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1.2 INTRODUCTION TO PRESSURIZED WATER REACTOR GENERATING SYSTEMS

Learning Objectives:

1. Define the following terms:

   a. Average reactor coolant system temperature (T_{avg}),
   b. Differential reactor coolant system temperature (ΔT),
   c. Departure from nucleate boiling (DNB),
   d. Departure from nucleate boiling ratio (DNBR),
   e. Power density (Kw/ft), and
   f. Seismic Category I.

2. Explain why T_{avg} is programmed to increase with an increasing plant load.

3. List two plant safety limits and explain the basis of each.

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No. R104P-01	Title: Intro. to PWR Systems	
Written by:Gibson	Approved by:	Date:04/93

1.0 Special Instructions and Training Aids

1.1 Vugraphs

2.0 References

2.1 10CFR

2.2 Westinghouse Technology Manual, Chapter 1.2

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No. R104P-01	Title: Intro. to PWR Systems	
Written by:Gibson	Approved by:	Date:04/93

3.0 Learning Objectives

3.1 Define the following terms:

a. Average RCS temperature (Tavg)
b. Differential RCS temperature (ΔT)
c. Departure from Nucleate Boiling (DNB)
d. Departure from Nucleate Boiling Ratio (DNBR)
e. Power Density (Kw/ft)
f. Seismic Category I

3.2 Explain why Tavg is programmed to increase with an increasing plant load.

3.3 List two plant safety limits and explain the basis of each.

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No. R104P-01	Title: Intro. to PWR Systems	
Written by:Gibson	Approved by:	Date:04/93

	4.0 Presentation
Figure 1.2-8	**4.0 Symbol review**
Figure 1.2-2	**4.1 Plant layout**
	a. Single Unit site - general layout
Figure 1.2-3	**4.2 Explain briefly duel cycle concept**
	[NOTE: Tell students to sit back and listen to this part of the lecture (vs feverish notetaking. They will hear the specifics of each system in detail in the individual lectures. They should listen for introduction and understanding of the big picture at this point. They will not be able to do this if they are trying to take notes regarding system details.]
Figure 1.2-1	**4.3 Systems Overview**
	a. Containment
	*Reactor vessel and core
Th= 609°F Tc= 547°F Tavg= 578°F ΔT= 62°F	*4 loops, only one (1) shown - Rx, SG, RCP Show T_{hot} & T_{cold} => $(T_{hot} + T_{cold})/2 = T_{avg}$ => $T_{hot} - T_{cold}$ = RCS ΔT
	*Pressurizer on one hot leg maintain saturated condition (650°F/2235 psig) heaters & sprays
	*Steam generators U-tubes barrier between primary and secondary FW to Steam (saturation) via heat transfer from primary
	*Containment building Seismic Category I Design Pressure & Temp. correspond to DBA analysis

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	b. Secondary penetration room *Main steam lines *Atmospheric relief valves (air operated, setpoint ~1040 psig) *5 Code Safeties/MSL (spring, 1st ~1064 psig, +12psig others) *MSIV *Seismic Category I boundary first restraint downstream of MSIV and check valve Penetration rooms are Seismic I also c. Turbine building *Not Seismic Main Steam System *Throttle (Stop) and Governor (Control) valves *HP turbine *MSRs *LP turbines *Main Condenser *Circulating Water *Main Generator Condensate and Feedwater *Main Condenser *Condensate (hotwell) pump *(Condensate booster pumps) *LP heaters for efficiency
HP+LP heaters add ~300°F	*Main Feedwater Pumps (steam turbine driven) *HP heaters for efficiency *Feed Regulating Valves *MFIV Seismic Category I boundary first restraint upstream of MFIV and check valve

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d. Auxiliary building
*Seismic Category I
*Safety equipment (ECCS,AFW)
*RCS auxiliary equipment (CVCS, Rx Makeup,CCW)

AFW
*Safety system-emergency feed to SGs (reactor heat sink)
*Auto start on loss of main feed or emergency signal(ESF/LOSP)
*CST = source of water

CVCS
*Non-safety
*Letdown
Regenerative HX
Orifices
Demins
VCT

*Charging
Charging pumps
Regenerative HX
Flow control valves

*Constant letdown, Charging flow rate based on pressurizer level.
*RCS volume control, chemical control

ECCS
*Mitigate LOCA => add inventory to RCS
*Mitigate MSLB => add poison (boric acid) to overcome +ρ added by overcooling
*RWST source of borated water

*High head injection
RWST => CCPs => 4 Cold Legs

*Safety injection (intermediate head)

*RHR (low head + shutdown cooling + long term recirc)

*Accumulators

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CCW
*Heat removal for potentially radioactive and ESFsystems
*Safety system
*Closed loop system
=>Surge tank => CCW pumps => CCW HX =>components

*CCW HX cooled by ESW (safety grade service water)

4.4 PWR T_{avg} Control Scheme

a. Introduction

1. Reactor output can be manipulated by:
control rods, boron concentration, steam demand

2. Automatic control systems designed for 5%/min ramp or 10% step change

3. In PWRs, the reactor follows the turbine (steam demand)

*Describe the process of changing steam demand (governor valve position), resulting effect on heat transfer in SG and T_{avg} response, and movement of rods(auto rod control) to control T_{avg}. {No Auto boron control system}.

The following discussion includes 3 possible modes of control of T_{avg}. (ie how do the rods know what to control T_{avg} to?)

b. Describe heat transfer from primary to secondary

$Q = U A \Delta T$

U=heat transfer coeff.
A=heat transfer area
ΔT = Tavg - Tstm *(Not same as RCS ΔT)*

c. To increase power output (Q) can either increase Tavg or decrease Tstm (ie to increase ΔT)... U and A are constant

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Figure 1.2-4	d. Constant T_{avg} Program *requires a large drop in $T_{stm}\backslash P_{stm}$ *great for primary control, RCS temp. and density constant less need for rod movement and changes in CVCS. *problems for secondary system, reduces secondary efficiency [turbine is sized for certain Pstm, if lower Pstm=>expansion through blading is different & amt of work by steam is less.] erosion of turbine blading [turbine inlet at lower temp & pressure, steam quality of last stages of turbine would be less (like riding a motorcycle in a rain storm!)] *for large PWRs, designing turbines to accept these conditions is cost prohibitive [NOTE: Navy uses constant T_{avg}]
Figure 1.2-5	e. Constant $T_{stm}(P_{stm})$ Program *Requires large increase in T_{hot} (T_{avg}) *Great for secondary Constant steam conditions,good for turbine & plant efficiency *Problems for the primary T_{hot} approaches saturation temperature at high power levels Volume changes cause perturbations in CVCS More rod motion to control temperature *Constant T_{stm}/P_{stm} not used for Westinghouse PWRs *Cost of upgrading primary to accept higher temperatures is prohibitive. [NOTE: B&W, with OTSGs, uses a constant P_{stm} for the ICS.]

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Figure 1.2-6 547°F - 578°F	f. Programmed (Sliding) Tavg Control *Compromise between two extremes => allows Tavg to rise some and Tstm/Pstm to drop some as power is increased. *Control parameters such that primary is operated within design limits and secondary is operated for maximum plant efficiency
	4.5 Plant Safety Limits a. Introduction *fuel integrity can be challenged due to producing more heat than can be removed => result is fuel melt *limits are placed on minimum heat removal capacity, and maximum heat (power) production *limit on max. RCS pressure (second barrier) to contain radioactivity if loss of fuel integrity *DNBR (heat removal) *Kw/ft (heat production) *RCS Pressure a. Limits upon important process variables necessary to reasonably protect the integrity of physical barriers that guard against the uncontrolled release of radioactivity. {Pressure, Temperature, Flow, Flux distribution} b. Departure from Nucleate Boiling
Figure 1.2-7	*The point during nucleate boiling where the steam produced forms an insulating layer over the fuel surface resulting in a rapid and significant increase in the surface temperature. *Some subcooled nucleate boiling is allowed and is a good heat transfer mechanism.

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c. Departure from Nucleate Boiling Ratio

$$*DNBR = \frac{\text{heat flux required for DNB to occur}}{\text{actual local heat flux}}$$

*minimum allowed is 1.3.
*DNB(R) not directly measurable => OTΔT trip

d. Pressure influences saturation => DNB

e. Flow induces greater heat transfer

$* \dot{Q} = \dot{m}\ Cp\ \Delta T$

*more flow, higher DNB<u>R</u>

<u>[Caution students concerning mixing up the terms DNB & DNBR]</u>

f. Temperature affects saturation => DNB

*sliding T_{avg} control keeps T_h from becoming too high

* Tech. Spec. limit on maximum RCS Tavg

g. Power Density (Kw/ft)

*Prevents too much power being generated in small core area
*Energy production per foot of fuel
*Fuel temp. not measurable => OPΔT trip

h. maximum RCS pressure

*110% of design pressure of 2500 psia = 2750 psia

*Hi pressure trip + Code safeties

5.0 Review Learning Objectives

2.0 REACTOR PHYSICS

Learning Objectives:

1. Define the following terms:

   a. K_{eff},
   b. Reactivity,
   c. Critical,
   d. Supercritical,
   e. Subcritical,
   f. Moderator temperature coefficient,
   g. Fuel temperature coefficient (Doppler),
   h. Void coefficient,
   i. Power coefficient,
   j. Power defect, and
   k. Neutron poison.

2. List two controllable and one uncontrollable neutron poison.

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No.R104P-02	Title: Reactor Physics	
Written by:Gibson	Approved by:	Date:04/93

1.0 Special Instructions and Training Aids

1.1 This module will cover the basic elements of lesson R304P-3 Reactor Physics (Chapter 2.1 in the Westinghouse PWR Systems Manual). The manual chapter is exactly the same (same text and figures) as R304P. Only the Learning Objectives are different (fewer and more basic). The students should be told that there is much more information in the chapter than they need to know for the purposes of this course, but the detail is included for completeness and consistency. The lecture and their study should focus on the Learning Objectives.

2.0 References

2.1 Westinghouse PWR Systems Manual, Chapter 2.1
2.2 T.S. 3.1.1.1, 3.1.1.2

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No.R104P-02	Title: ReactorPhysics	
Written by:Gibson	Approved by:	Date:04/93

3.0 Learning Objectives

3.1 Define the following terms:

a. Keff
b. Reactivity
c. Critical
d. Supercritical
e. Subcritical
f. Moderator Temperature Coefficient
g. Fuel Temperature Coefficient (Doppler)
h. Void Coefficient
i. Power Coefficient
j. Power Defect
k. Poison

3.2 List two controllable and one uncontrollable poison.

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No.R104P-02	Title: Reactor Physics	
Written by:Gibson	Approved by:	Date:04/93

	4.0 Presentation
	4.0 Fission Process
	4.0.1 Fission Event
Equation Page 2-1	U-235 + n ---> (U-236)*
	(U-236)* ---> FP1 + FP2 + 2.43 n + Energy
a.Table, Page 2-2	a. Energy distribution
b.Table, Page 2-2	b. 2.43 n is an average
Figure 2-1	
	4.0.2 Neutron Generation and Lifetime
Figure 2-2	a. Power level α # of fissions α neutron population
	[Section 2.4, Nuclear Cross Section is not covered in this lecture.]
	4.1 Keff
	4.1.1 Definition
	(<u>#neut. avail. for fission in current gen.</u>) #neut. avail. for fission in previous gen.
	4.1.2 During the lifetime of a neutron, their are several possible events it may undergo. Each event is described by a factor. The product of these factors is Keff.
	4.1.3 Keff= $\varepsilon L_f p L_t f \eta$ (another acceptable definition)
Table 2-2 Page 2-5	Describe in simple terms each of the factors. Discuss neutron balance. ε - fast fission factor L_f - fast nonleakage factor p - resonance escape probability L_t - thermal nonleakage factor f - thermal utlilization factor (explain operator control) η - neutron production factor

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
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4.1.4 Subcritical, critical, supercritical definitions

4.2 Reactivity (ρ)

4.2.1 Definition of reactivity in terms of Keff - how far a reactor is from critical

$$\rho = \frac{(keff-1)}{keff}$$

4.2.2 ΔK/K, PCM, % ΔK/K

4.2.3 Parameters that affect
4.2.3.1 Fuel depletion
4.2.3.2 Rod Motion
4.2.3.3 Temperature changes (fuel and mod.)
4.2.3.4 Poison changes
4.2.3.5 Boron changes

4.3 Reactivity Coefficients - a change of reactivity with respect to(or resulting from)a change in some parameter

$$\frac{\Delta\rho}{\Delta parameter}$$

4.3.1 Major coefficients

Figures 2-5,6,7

4.3.2.1 Fuel Temperature Coefficient (Doppler)

a. Definition (Δρ/ΔTfuel)

b. Units ($\frac{PCM}{°F}$)

c. Resonance capture (the concept)

d. Doppler only power coefficient($\frac{PCM}{\%\ power}$)

e. Doppler only Power Defect ($\frac{PCM}{Total\ \Delta\ power}$)

f. Change of Doppler over core life - thermal conductivity, Pu-240, clad contact

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No.R104P-02	Title: Reactor Physics	
Written by:Gibson	Approved by:	Date:04/93

Figure 2-8	4.3.2.2 Moderator Temperature Coefficient (MTC) a. Definition ($\Delta\rho/\Delta$Tmod) b. Units ($\frac{PCM}{°F}$) c. Temperature effect on density d. Boron effect on MTC e. Change in MTC over core life f. Requirements of MTC (neg., Tavg TS value) g. Purpose of burnable poison (neg. MTC)
Figure 2-9	4.3.2.3 Total Power Coefficient a. Definition ($\Delta\rho/\Delta$ power level) b. Units ($\frac{PCM}{\%\ power}$)
Figure 2-10	c. Void coefficient definition ($\Delta\rho/\Delta$ %voids) d. Total Power Defect, explain operator use for power changes, explain rod height requirement
	4.4 Poisons a. Definition (unproductive capture) b. Rods and boron - Controllable (tie to f) c. Xenon and samarium - Uncontrollable
Figures 2-11 - 15	4.4.1 Xenon a. Importance (lot of it, captures lots of thermal neutrons, changes rapidly - not under operators control) b. Production and removal
Figure on Page 2-13	U-235 fission → Xe-135 → n capture to Xe-136 I-135 decay → Xe-135 → decay to Cs135 c. Effect of power changes on Xenon

	4.4.2 Samarium a. Importance b. Production
Equation Page 2-14	$$\text{Nd-149} \xrightarrow[\text{1.7 hr.}]{\beta} \text{Pm-149} \xrightarrow[\text{53 hr.}]{\beta} \text{Sm-149 (stable)}$$
Figures 2-16 - 19	c. Removal by burnout d. Effect of power change on Sm
	4.4.3 Control rods
Figure 2-20	a. Differential rod worth b. Integral rod worth c. Effect of flux distribution on rod worth d. Operation with all rods out
	4.4.4 Boron a. Chemical shim Boron-10 b. Effect on rod position, flux distribution c. Removed to compensate for fuel depletion
	[Section 2.8, Reactor Kinetics is not covered.]
ObjectivesVugraph	**5.0 Review Objectives**

3.1 REACTOR CORE AND VESSEL CONSTRUCTION

Learning Objectives:

1. State the purpose of the following major reactor vessel and core components:

   a. Internals support ledge,
   b. Thermal shield,
   c. Secondary support assembly,
   d. Fuel assembly,
   e. Control rod,
   f. Upper and lower core support structures,
   g. Primary and secondary source assemblies,
   h. Burnable poison rod assemblies, and
   i. Thimble plug assemblies.

2. Describe the flow path of reactor coolant from the inlet nozzles to the outlet nozzles of the reactor vessel.

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No.R104P-03	Title: Reactor Core and Vessel Construction	
Written by:Gibson	Approved by:	Date:12/92

1.0 Special Instructions and Training Aids

1.1 Emphasis should be placed on flow paths thru core so the student understands heat removal process during power operations, natural circulation and blowdown during LOCA situation. The design and operation of the CRDM will be covered in lesson SYS 08-0 - Rod Control System.

1.2 Viewgraphs 3.1-1 thru 17

1.3 Vessel & core model, Fuel Assembly Mockup, Spring clip grid assembly, cutaway fuel rod, control rod assembly, control rod drive shaft, vessel o-ring cutaways

2.0 References

2.1 W PWR TechnologyManual, Chapter 3.1
2.2 Callaway FSAR
2.3 Callaway/Wolf Creek Drawings
2.4 Westinghouse Training Manual NPS-215-1
2.5 T.S. 3.4.6.2 Pressure Boundary Leakage
T.S. 3.4.4.9 RCS Pressure Temperature Limits
(a) Surveillance of reactor vessel specimens

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No.R104P-03	Title: Reactor Core and Vessel Construction	
Written by:Gibson	Approved by:	Date:12/92

3.0 Objectives

3.1 State the purpose of the following major reactor vessel and core components:

a. Internals support ledge (pg. 3.1-2)
b. Thermal shield (pg. 3.1-2)
c. Secondary support assembly (3.1-2)
d. Fuel Assembly (pg. 3.1-3)
e. Control Rod (pg. 3.1-15 & 3.1-16)
f. Upper-& Lower Core Suppore Structures(pg.3.1-2&3)
g. Primary and Secondary Source Assemblies (pg. 3.1-4)
h. Burnable Poison Rod Assemblies (pg. 3.1-4)
i. Thimble Plug Assemblies(pg.3.1-4)

3.2 Describe the flow path of reactor coolant from the inlet nozzles to the outlet nozzles of the reactor vessel. (pg. 3.1-2)

WESTINGHOUSE TECHNOLOGY LESSON PLAN

Lesson No.R104P-03	Title: Reactor Core and Vessel Construction	
Written by:Gibson	Approved by:	Date:12/92

	4.0 Presentation
Purposes Figure 3.1-3 Figure 3.1-4 (Note: Simplified & Detailed Figs. - Can put one on each projector)	**4.1 Purposes** (a) provide heat source for NSSS (b) provide first barrier (fuel cladding) to release of fission products (c) support and align fuel assemblies (d) provide flowpath for heat removal
	4.2 Vessel Construction
	4.2.1 General size (a) height - ~~43'~~ ? 44' (b) diam. - ~~17'~~ ? 14'-10
Figure 3.1-2	4.2.2 Core Cross Section (a) explain relationship between components
	4.2.3 Vessel head (a) closure studs (54) (b) O-ring seals (2) (c) head penetrations 1. CRDM adapters 2. head vent 3. incore thermocouples
	4.2.4 Lower head - welded to vessel, 58 penetrations for incore system.
Figure 3.1-1	4.2.5 Vessel supports - 4 support pads bolted to primary shield wall air or water cooled.
Figure 3.1-5	4.2.6 Lower core support structure (a) core barrel - upper flange on vesselsupport ledge. Key/keyway (6) (b) core baffle - former plates, bypass flow. (c) core support forging - welded to bottom of core barrel. (d) lower core plate - core boundary, locating pins, flow holes.

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No.R104P-03	Title: Reactor Core and Vessel Construction	
Written by:Gibson	Approved by:	Date:12/92

	(e) support columns - between lower core plate and lower support forging. (f) diffuser plate - on support columns, prevent vortexing. (g) secondary support assembly - connected to lower support forging, only for flange failure, prevent misalignment of RCCA's. (h) thermal shield - reduce radiation damage to vessel. (i) specimen baskets - welded to thermal shields, vessel materials, removed with special tool.
Figure 3.1-7	4.2.7 Upper core support structure -removed for refueling. (a) upper support assembly (b) upper core plate - locating pins, flow holes. (c) support columns (d) control rod guide tubes
	4.3 Core Construction
Figure 3.1-9 & 10 (b) Figure 3.1-8 (f) Figure 3.1-11	4.3.1 Fuel assemblies (a) 193 in a 4 loop plant (b) identical construction, different enrichments (c) bottom nozzle - stainless steel (d) top nozzle - stainless steel (e) guide tubes - support, zirc-4 (24 for rodlets, 1 incore) (f) spring clip grids - inconel (g) fuel pins - zirc-4 clad, $U0_2$ pellets, helium (254)
Figure 3.1-12	4.3.2 Control rods (a) 53 in a 4 loop plant (b) silver - indium - cadmium (85/15/5) in a stainless steel tube (may also use B_4C or Hafnium) (c) hub (d) spider (e) drive shaft
Figure 3.1-13	

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No.R104P-03	Title: Reactor Core and Vessel Construction	
Written by:Gibson	Approved by:	Date:12/92

Figure 3.1-14	4.3.3 Burnable poison rods (a) purpose - limit amount of boric acid in new core to maintain ~~MTC ≤0~~. MTC within limits (b) 12, 16, or 20 rodlets, thimble plug devices (c) worth - 7% BOL to .8% EOL
(b)Figure 3.1-15 (c) Figure 3.1-16	4.3.4 Neutron sources (a) purpose - reliable reading on source range. (b) primary sources (2) - normally Cf-252 spontaneous fission, first core only. (c) secondary sources (2) - Sb-Be, 60 day half life.
*Equation not in manual - for info.	${}_{51}Sb^{123} + {}_{0}n^{1} \Rightarrow ({}_{51}Sb^{124})^{*} \xrightarrow{60d} {}_{52}Te^{124} + {}_{-1}\beta^{0} + \gamma$ $\gamma + {}_{4}Be^{9} \Rightarrow {}_{4}Be^{8} + {}_{0}n^{1}$ (d) located near source range detectors
Figure 3.1-13	4.3.5 Thimble plugs - limit bypass flow
Figure 3.1-6	4.3.6 Flowpaths (a) From inlet nozzles - between core barrel and vessel around thermal shield - up through lower core support forging - diffuser plate - lower core plate - through and around fuel assemblies - upper core plate - core barrel nozzles - vessel outlet nozzles. (b) Bypass flows - 4% 1. Nozzle bypass - 1% 2. RCCA guide tubes - 2% 3. Baffle former plates - .5% 4. Head cooling - .5%
Figure 3.1-17	4.3.7 Control Rod Drive Mechanisms (a) Show Figure & mention that this will covered in detail in a later lesson (Rod Control).
Review ObjectivesVugraph	**5.0 Review Learning Objectives**

3.2 REACTOR COOLANT SYSTEM

Learning Objectives:

1. State the purpose of the reactor coolant system.

2. List in flow path order and state the purpose of the following major components of the reactor coolant system:

   a. Reactor vessel,
   b. Steam generator, and
   c. Reactor coolant pump.

3. List and state the purpose of the following reactor coolant system penetrations:

   a. Hot leg
      1. Pressurizer surge line,
      2. Resistance temperature detector, and
      3. Residual heat removal system suction.

   b. Intermediate (crossover) leg
      1. Chemical and volume control system letdown connection and
      2. Elbow flow taps.

   c. Cold leg
      1. Pressurizer spray line,
      2. Resistance temperature detector,
      3. Common emergency core cooling system connections for residual heat removal, safety injection, and cold leg accumulators,
      4. High head injection, and
      5. Chemical and volume control system charging.

4. Describe the flow path through the steam generator for both the reactor coolant system and steam side.

5. State the purpose of the following components of the reactor coolant pump:

   a. Thermal barrier heat exchanger,
   b. Shaft seal package,
   c. Flywheel, and
   d. Anti-reverse rotation device.

6. State the purpose of the pressurizer and the following associated components:

   a. Code safety valves,
   b. Power operated relief valves,
   c. Power operated relief valves block valves,
   d. Pressurizer relief tank,
   e. Pressurizer spray valves, and
   f. Pressurizer heaters.

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No.R104P-04	Title: Reactor Coolant System	
Written by:Gibson	Approved by:	Date:12/92

1.0 **Special Instructions and Training Aids**

1.1 This module will cover the design and operation of the RCS asdescribed in Chapter 3.2 of the Westinghouse PWR Technology Manual. Reactor pump seals should be introduced in this lecture, but will be covered in detail in CVCS. Steam generator flowpaths are covered in this module, details of steam generator operation are covered in the Secondary Systems lectures.

1.2 Viewgraphs 3.2-1 thru 8

2.0 **References**

2.1 PWR Technology Manual, Chapter 3.2
2.2 Callaway FSAR
2.3 Callaway/Wolf Creek Drawings
2.4 Westinghouse Training Manual, NPS-215

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No.R104P-04	Title: Reactor Coolant System	
Written by:Gibson	Approved by:	Date:12/92

Objectives Vugraph

3.0 Objectives

3.1 State the purpose of the Reactor Coolant System (RCS).

3.2 List in flowpath order and state the purpose of the following major components of the RCS:

a. Reactor vessel
b. Steam generator
c. Reactor coolant pump

3.3 List and state the purposes of the following RCS penetrations:

a. Hot Leg
   1. pressurizer surge line
   2. resistance temperature detector (RTD)
   3. RHR suction

b. Intermediate (crossover) leg
   1. CVCS letdown connection

c. Cold Leg
   1. pressurizer spray line
   2. resistance temperature detector (RTD)
   3. common Emergency Core Cooling System (ECCS) connection for RHR, SI, Accumulator
   4. High head injection
   5. CVCS charging

3.4 Describe the flow path through the steam generator for both the RCS and steam side..

3.5 State the purpose of the following components of the reactor coolant pump.

a. thermal barrier heat exchanger
b. shaft seal package
c. flywheel
d. anti-reverse rotation device

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No.R104P-04	Title: Reactor Coolant System	
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3.6 State the purpose of the pressurizer and the following associated components:

a. code safety valves
b. power operated relief valves (PORV)
c. PORV block valves
d. pressurizer relief tank (PRT)
e. pressurizer spray valves
f. pressurizer heaters

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No.R104P-04	Title: Reactor Coolant System	
Written by:Gibson	Approved by:	Date:12/92

	4.0 Presentation 4.1 Purposes 4.1.1 Transfer heat from reactor to steam generators 4.1.2 Barrier to radioactivity
	4.2 System Description
RCS Figure 3.2-1 *Table 3.2-1*	4.2.1 Four loops connected in parallel a. each loop contains -S/G -RCP b. pressurizer connected to one loop by surge line
	4.2.2 All RCS components located inside containment.
RCS Loops Figure 3.2-2	4.3 Flowpath 4.3.1 Reactor vessel 4.3.2 Hot leg- 29"I.D.- Pzr surge line 4.3.3 Steam generator 4.3.4 Intermediate leg-31" I.D. 4.3.5 RCP 4.3.6 Cold leg- 27.5" I.D. - Pzr spray line
	4.4 Pressurizer
Pressurizer Figure 3.2-2 Figure 3.2-3	4.4.1 Functions a. pressurize RCS during plant start-up b. maintain normal RCS pressure during steady state operation c. limit pressure changes during RCS transients d. prevent RCS pressure from exceeding design value
(Note: Psat=2235 Tsat~653°F)	

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No.R104P-04	Title: Reactor Coolant System	
Written by:Gibson	Approved by:	Date:12/92

4.4.2 Description
- a. 1800 Ft3
- b. spray nozzle
- c. heater elements (78)- 1800Kw
- d. safety valves
- e. PORV's

4.4.3 Operations
- a. normal -steady state, variable heaters and bypass spray flow
- b. transients- backup heaters and spray flow
- c. overpressure protection- PORV's and code safety valves

Figure 3.2-2

4.5 Pressurizer Relief Tank

4.5.1 Functions
- a. collects, condenses, and cools discharge from Pzr relief and safety valves

4.5.2 Description
- a. 1800 Ft3
- b. protected by 2 rupture discs which relieve to containment
- c. designed to condense and cool a discharge of Pzr steam equivalent to 110% of the full power Pzr water level setpoint

4.5.3 Operation
- a. operated ~ 3/4 full of water with nitrogen cover gas
- b. steam discharged thru sparger at bottom of tank

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No.R104P-04	Title: Reactor Coolant System	
Written by:Gibson	Approved by:	Date:12/92

Figure 3.2-4

4.6 Steam Generators

4.6.1 Functions

a. boundary between primary and secondary
b. transfers energy from primary to secondary

4.6.2 Description

a. carbon steel vertical shell and U-tube
b. primary clad with SS
c. inconel divider plate
d. inconel clad tube sheet (primary)
e. 3,388 inconel tubes, 0.875 in. OD, 0.050 in. thick
f. 44,000 Ft2 heat transfer area
g. feed ring
h. wrappers
i. tube support plates (7)
j. anti-vibration bars
k. swirl vane seperators
l. chevron seperators

4.6.3 Operation

a. Primary flowpath
b. Secondary flowpath
   - -inlet nozzle
   - -feedring+j-tubes
   - -downcomer annulus
   - - mixes with recirc water
   - - level measured in downcomer
   - - tube bundle, producing steam - water mixture
   - - swirl-vane moisture separator
   - - chevron separator
   - - outlet nozzle (<0.25% moisture)

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No.R104P-04	Title: Reactor Coolant System	
Written by:Gibson	Approved by:	Date:12/92

Figure 3.2-5

4.7 Reactor Coolant Pump

4.7.1 Hydraulic Section

a. single stage centrifugal
b. suction
c. impeller
d. diffuser
e. outlet
f. bearing
g. thermal barrier and heat exchanger

Figure 3.2-6

4.7.2 Seal section

a. #1 seal
- film riding, controlled leakage

b. #2 seal
- rubbing face type
- backup for #1 seal
- full operating pressure capability

c. #3 seal (Model 93A-1)
- rubbing face, double dam
- double dam permits injection of clean water

4.7.3 Motor Section

a. vertical, six pole, squirrel-cage, induction motor
- non-vital 6.9KV
- 6000 HP

Figure 3.2-8

b. flywheel
- keyed to top of shaft
- inertia extends coastdown, initiates natural circulation

c. anti-reverse rotation device
- prevents reverse flow
- prevents excessive starting current
- ratchet pawls on bottom of flywheel engage serrated plate on motor frame

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No.R104P-04	Title: Reactor Coolant System	
Written by:Gibson	Approved by:	Date:12/92

Figure 3.2-7	4.8 Instrumentation a. flow - elbow flow meters b. temperature -hot and cold leg RTDs c. pressure and level - pressurizer
Figure 3.2-7	4.9 Penetrations a. common to all loops - hot leg injection/recirc from SIS - hot leg RTD's (well mounted) *narrow range (530 - 650°F) *wide range(0-700°F) - elbow flow detector (crossover leg) - drain to RCDT - cold leg RTD's (well mounted) (narrow and wide range) - cold leg injection from ECCS b. specific to individual loops - surge line (4) - RHR supply (1&4) - CVCS letdown (3) - CVCS charging (1&4) - spray lines (1&2) - excess letdown (4)
	4.10 Valves a. Constructed primarily of SS b. Provided with double-packed stuffing boxes and gland leakoffconnections c. valves > 3 inch d. valves containing radioactive fluid e. valves which normally operate > 212°F f. all throttling control valves

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No.R104P-04	Title: Reactor Coolant System	
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	g. Reactor Coolant Loop Isolation Valves -optional on Westinghouse units -designed for maintenance use -extensive interlock system
Objectives Vugraph	**5.0 Review**

4.0 CHEMICAL AND VOLUME CONTROL SYSTEM

Learning Objectives:

1. List the purposes of the chemical and volume control system.

2. List in flow path order and state the purpose of the following major components of the chemical and volume control system:

    a. Regenerative heat exchanger,
    b. Letdown orifice,
    c. Letdown heat exchanger,
    d. Ion exchangers,
    e. Letdown filter,
    f. Volume control tank, and
    g. Charging pump.

3. Identify the components of the chemical and volume control system that are used to purify the reactor coolant.

4. List the makeup system components used to either borate, dilute, or makeup a blended flow of boric acid to the reactor coolant system.

5. Explain why the following chemicals are added to the reactor coolant system:

    a. Lithium hydroxide,
    b. Hydrogen,
    c. Hydrazine, and
    d. Boric acid.

6. List the components in the emergency boration flow path and identify one plant condition which would require its use.

9. Identify the changes in the chemical and volume control system flow path that occur upon the receipt of an engineered safety features actuation signal.

10. State the reasons for supplying seal injection to the reactor coolant pumps.

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No.R104P-05	Title: Chemical and Volume Control and Pressurizer Level Control Systems	
Written by: Gibson	Approved by:	Date: 11/92

1.0 Special Instructions and Training Aids

1.1 The student must understand the design and operation of the CVCS and understand the realignment of the system during accident conditions. RCP seals/seal injection should be covered in detail in this lesson. An introduction was provided in the RCS lesson. The Pressurizer Level Control System is also covered in this lesson.

1.2 Viewgraphs 4-1 thru 6 & 10.3-1 & 2.

2.0 References

2.1 Westinghouse Technology Manual Chapters 4 & 10.3

2.2 Tech. Specs. Section 3/4.1

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No.R104P-05	Title: Chemical and Volume Control and Pressurizer Level Control Systems	
Written by:Gibson	Approved by:	Date:11/92

3.0 Objectives (CVCS, Chapter 4)

3.1 List the purposes of the CVCS.

3.2 List in flowpath order and state the purpose of the following major components of the CVCS:
- a. Regenerative heat exchanger
- b. Letdown orifice
- c. Letdown heat exchanger
- d. Demineralizers (ion exchangers)
- e. Letdown filter
- f. Volume control tank (VCT)
- g. Charging pump

3.3 Identify the components in the CVCS that are used to purify the reactor coolant.

3.4 List in flowpath order the makeup system components used to either borate, dilute, or makeup a blended flow of boric acid to the Reactor Coolant System.

3.5 Explain why the following chemicals are added to the RCS:
- a. Lithium hydroxide
- b. Hydrogen
- c. Hydrazine
- d. Boric acid

3.6 List the components in the emergency boration flowpath, and identify one plant condition which would require its use.

3.9 Identify the changes in the CVCS flowpath that occur upon the receipt of an engineered safety features actuation signal.

3.10 State the reasons for supplying seal injection to the RCPs.

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No.R104P-05	Title: Chemical and Volume Control and Pressurizer Level Control Systems	
Written by: Gibson	Approved by:	Date: 11/92

Purposes
Listed on Page 4-1 in a slightly different order.

4.0 Presentation (CVCS)

4.1 Purposes

4.1.1 ***Reactivity Control*** -Adjust the chemical neutron absorber makeup by regulating the concentration of boric acid in the RCS to control reactivity changes due to fuel burnup,Xe, poisons, etc

4.1.2 ***Reactor Coolant Inventory*** -Maintains the coolant inventory in the RCS within the allowable press. level range through all modes of plant operations.

4.1.3 ***Reactor Coolant Purification*** - Controls the RCS water chemistry and activity levels by removing fission and corrosive products during ops.

4.1.4 ***Chemistry Control*** - Provides a means of adding chemicals to the RCS to control pH & 0_2 concentrations.

4.1.5 ***Seal Water Injection*** flow - Supply filtered water to the four (4) RCPs, to cool and lubricate the pumps lower radial bearing and seals.

4.1.6 Provides a means of ***Emergency Boration*** of the RCS for ATWS, stuck rod(s) or dilution accident.

4.1.7 ***Emergency Core Cooling*** - Other than the centrifugal charging pumps and associated valves and piping the CVCS is not required to function on an ESF actuation.

4.1.8 Process RCS water for reuse - Sized to accommodate excess RCS effluent discharged into the CVCS and to reprocess for reuse and to limit the offsite shipment of effluents(***Boron RecycleSystem***).

4.2 System Description

Figure 4-1

4.2.1 Subsystems

a. Letdown
b. Volume control and makeup
c. Seal injection flow
d. Charging

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
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Figure 4-2	4.2.2 Basic flowpath a. Heat exchangers b. Orifices c. Demineralizers d. Filter e. VCT f. Charging pumps g. Seal injection h. Normal Charging Line i. Heat exchanger
	4.3 Detailed System Descriptions
a. 545°F - 290°F 130°F - 495°F c. 115°F d. 350 psig f. $30ft^3$ h. 60 -74% i. $400ft^3$	4.3.1 Components in system flowpath a. Regen. Hx b. Orifice isolation valves c. Letdown heat exchanger d. Pressure control valve (backpressure) e. Temperature divert value f. Demineralizers 1. mixed bed (Li-OH or H-OH)) 2. cation(removes Li) g. Filter h. VCT level control valve i. VCT (Normal. suction., dearate) j. Charging pumps k. Seal injection path l. Charging paths 1. Normal 2. Alternate 3. Auxiliary Spray
Seal Injection Figure 4-4 Figure 4-3 CVCS flow balance	
Rx Makeup System Figure 4-5	4.3.2 Makeup control system a. Purpose 1. Leakage from RCS 2. Boron concentration changes 3. Makeup to aux. sys.

WESTINGHOUSE TECHNOLOGY LESSON PLAN

Lesson No.R104P-05	Title: Chemical and Volume Control and Pressurizer Level Control Systems	
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	b. Supplies 1. Primary makeup water 2. 4% weight boric acid
	c. Makeup modes 1. Auto 2. Dilute 3. Alt. Dilute 4. Borate
Figure 4-2, 4-5	d. Emergency Borate
Boron Recycle System Purposes	4.3.2 Boron Recycle System a. Collects borated water from the RCS and reprocesses this water for reuse b. Reusing limits the amount of waste water treatment of radioactive effluents.
Figure 4-6	c. General Description 1. Holdup tanks 2. Ion Exchangers 3. Boric Acid Evaporator *concentrates discharge points *condensate discharge points d. Boric Acid Evaporator 1. Flowpath *Preheater *Eductor *Gas stripping column *Evaporator *Bottoms *Absorption tower Reflux from distillate pumps *Distillate cooler
	5.0 Review
Review Figure 4-2 Figure 4-5 Figure 4-4 Figure 4-6	5.1 Review major flowpaths *Letdown *Charging *Makeup *Seal injection *Boron recovery
Objectives Vugraph	5.2 Review Learning Objectives

5.1 EMERGENCY CORE COOLING SYSTEMS

Learning Objectives:

1. Explain why emergency core cooling systems are incorporated into plant design.

2. Describe the operation of the emergency core cooling systems during the following conditions:

   a. Injection phase and
   b. Recirculation phase.

3. State the purposes of the residual heat removal system.

4. Describe the residual heat removal system flow path, including suction supplies, discharge points, and major components during the following operations:

   a. Decay heat removal,
   b. Injection phase, and
   c. Recirculation phase.

5. State the purposes of the following systems:

   a. Accumulator injection system,
   b. Safety injection pump system, and
   c. High head injection system.

6. State the purpose of the following components:

   a. Refueling water storage tank and
   b. Containment recirculation sump.

7. List the order of emergency core cooling systems injection during the following abnormal conditions:

   a. Inadvertent actuation (at normal operating temperature and pressure),
   b. A small (slow depressurization of the reactor coolant system) break loss of coolant accident, and
   c. A large loss of coolant accident.

WESTINGHOUSE TECHNOLOGY LESSON PLAN

Lesson No. R104P-12	Title:Emergency Core Cooling System	
Written by: Gibson	Approved by:	Date: 9/92

1.0 Special Instructions & Training Aids

1.1 Westinghouse Technology Manual

1.1.1 Objectives Viewgraph

1.1.2 Figures 5.1-1, 5.1-2, 5.1-3, 5.1-5, 5.1-8

2.0 References

2.1 W Technology Manual Chapter 5.1

2.2 Callaway FSAR

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No. R104P-12	Title:Emergency Core Cooling System	
Written by: Gibson	Approved by:	Date: 9/92

Objectives Viewgraph	**3.0 Objectives (ECCS)** 1. Explain why Emergency Core Cooling Systems are incorporated into plant design. 2. Describe the operation of the Emergency Core Cooling Systems during the following conditions: a. Injection phase b. Recirculation phase 3. State the purposes of the Residual Heat Removal System(RHR). 4. Describe the RHR system flowpath including suction supplies, discharge points, and major components during the following operations: a. Decay heat removal b. Injection phase c. Recirculation phase 5. State the purpose of the following systems: a. Accumulator System b. Safety Injection System c. High Head Injection System 6. State the purpose of the following components: a. Refueling Water Storage Tank (RWST) b. Containment Recirculation Sump 7. List the order of ECCS injection during the following conditions: a.Inadvertent actuation (at normal RCS operating temperature and pressure) b.Small break loss of coolant accident. (slow depressurization) c.Large loss of coolant accident (LOCA).

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No. R104P-12	Title:Emergency Core Cooling System	
Written by: Gibson	Approved by:	Date: 9/92

4.0 Presentation (ECCS)

Purposes
Page 5.1-1

4.1Purposes of ECCS

1.Emergency Core Cooling Systems(5.1.2.1)
- a. Provide core cooling to minimize fuel damage follow ing a loss of coolant accident (LOCA).
- b. Provide additional shutdown margin following a steam line break accident

2. Residual Heat Removal System (active system)(5.1.2.2)
- a. Provide low pressure, high volume safety injection to complete the reflooding of the core following a LOCA.
- b. Provide a flowpath and heat sink for long term core cooling following a LOCA.
- c. Provide for decay heat removal during a plant cooldown below 350°F.

3. Accumulators (passive system) (5.1.2.3)
   Rapidly reflood the core following a LOCA

4. Safety Injection Pump System (active system)(5.1.2.4)
   Provide intermediate pressure, low volume safety injection for small to intermediate size LOCAs.

5.High Head Safety Injection System (active system) (5.1.2.5)
- a. Provide high pressure, low volume safety injection for small to intermediate size LOCAs.
- b. Provide charging flow for the Chemical Volume and Control System during normal operations.

Overview
Figure 5.1-1

4.2 System Description

4.2.1 Adds inventory to RCS tomakeup for loss during LOCA
Adds poison to counteract MTC from cooldown during a steamline break

4.2.2 Subsystems

4.2.2.1 Accumulators
4.2.2.2 High Head Safety Injection (CVCS)
4.2.2.3 Safety Injection Pumps - Intermediate Head (pressure)
4.2.2.4 RHR - Low Head (pressure)

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
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Written by: Gibson	Approved by:	Date: 9/92

	4.2.2 RWST 4.2.2.1 Borated water source for active ECCS components
RHR Figure 5.1-2	**4.3 Residual Heat Removal System** 4.3.1 System Description 4.3.1.1 Source of water (RWST) 4.3.1.2 Pumps 4.3.1.3 Heat Exchangers 4.3.1.4 Cold Legs (Other discharge paths to be covered later) 4.3.1.5 Two trains 4.3.2 Plant Cooldown 4.3.2.1 Describe first phase of cooldown 4.3.2.2 RHR placed in service when RCS <350°F and 425 psig 4.3.2.3 Show flowpath from hot leg thru system to cold legs. 4.3.2.4 CCW to HX *with both loops in service and CCW @ 100°F, RHR will reduce RCS temperature to 140°F in 20 hours 4.3.2.5 Decay heat removal 4.3.2.6 Crossconnect to CVCS for purification during shutdown 4.3.3 ECCS Function 4.3.3.1 Injection Phase *Suction on RWST; discharge to coldlegs *170 psig, 4500 gpm 4.3.3.2 Recirculation Phase *Suction on containment sump *Auto shift when RWST level is low *Discharge to: Cold legs Charging Pump Suction SI Pump Suction
Recirc. Sump Figure 5.1-3	4.3.4 Containment Recirculation Sump 4.3.4.1 Collects RCS discharge during LOCA

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No. R104P-12	Title:Emergency Core Cooling System	
Written by: Gibson	Approved by:	Date: 9/92

Accumulators Figure 5.1-4	**4.4 Accumulator System** 4.4.1 2000 ppm boric acid 4.4.2 600 psig, N_2 overpressure 4.4.3 Isolation valve open and power removed 4.4.4 Check valves 4.4.5 Common injection line with RHR and SI
SI system Figure 5.1-5	**4.5 Safety Injection Pump System** 4.5.1 Normal OPS - standby 4.5.2 1500 psig, 550 gpm 4.5.3 RWST suction discharge to cold legs 4.5.4 Recirculation phase lineup
High head inj. Figure 5.1-6	**4.6 High Head Injection System** 4.6.1 Show normalflowpath 4.6.2 ESF Actuation Signal System Realignment * Charging pumps start * VCT outlet valves * Miniflow recirc. valves * Charging header isolation valves * RWST suction valves * BIT inlet and outlet valves

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
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Integrated Ops. **SBLOCA** Figure 5.1-1 Figure 5.1-8	**4.7 Integrated Operations** 4.7.1.1 Injection phase small break 4.7.1.1 ESF Actuation Signal 4.7.1.2 All pumps start taking suction from RWST 4.7.1.3 Small rate of decrease in pressure *High Head Injection *Intermediate Head *Accumulators *RHR
Large LOCA Figure 5.1-1	4.71.2 Injection Phase Large Break 4.7.2.1 ESF Actuation Signal 4.7.2.2 All pumps start taking suction fromRWST 4.7.2.3Pressure drops out of indicatingrange *Cold Leg Accumulator *Pumps
Recirc. Phase Figure 5.1-2 Note: Only cold leg recirc. is covered in this course.	4.7.3 Recirculation phase 4.7.3.1 RWST Level Low w/ 4.7.3.2 Containment sump level high 4.7.3.3 Suction valves switch *Auto in some plants
Review	**5.0 Review Learning Objectives**

5.2 CONTAINMENT AND AUXILIARY SYSTEMS

Learning Objectives:

1. State the purpose of the containment building.
3. State the purpose of the containment hydrogen recombiners.
4. State the purpose of the containment fan coolers during accident and non-accident conditions.
5. State the purpose of the containment spray system.
6. Explain why sodium hydroxide is added to the containment spray.

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No. R104P-5.2	Title: Containment	
Written by: Gibson	Approved by:	Date:2/94

1.0 Special Instructions and Training Aids

1.1 Small containment mockup showing tendons.
1.2 Piece of tendon.

2.0 References

2.1 PWR Technology Manual, Chapter 5.2
2.2 10 CFR 50 App. A
2.3 PPSP Instructor Guide

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No. R104P-5.2	Title: Containment	
Written by: Gibson	Approved by:	Date:2/94

3.0 Objectives

1. State the purpose of the containment building.

3. State the purpose of the containment hydrogen recombiners.

4. State the purpose of the containment fan coolers during accident and non-accident conditions.

5. State the purpose of the Containment Spray System.

6. Explain why sodium hydroxide is added to the containment spray.

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No. R104P-5.2	Title: Containment	
Written by: Gibson	Approved by:	Date:2/94

	4.0 Presentation
	4.1.1 Purposes
	1. Provide a barrier to prevent the escape of radioactivity during normal and accident conditions.
	2. Provide protection against internally and/or externally generated missiles.
	3. Provide biological shielding during normal and accident conditions.
	4. Provide Seismic Category I supports for the reactor coolant and its associated systems.
	4.1.2 Design Bases
	1. Withstand temperature and pressure of a design basis LOCA
	2. Release due to DBA < Part 100 dose limits
Figure 5.2-1	3. Exclusion area (<25R whole body, 300 thyroid in 2 hrs)
	4. Low Population Zone (<25Rwhole body, 300 thyroid total)
	4.1.3 Containment Types
	1. Reinforced concrete - steel liner
	2. Full steel - usually with a shield building
Figure 5.2-2	3. Prestressed concrete - steel liner 1. Liner 2. Reactor cavity 3. Primary loop compartment wall 4. Primary shield wall 5. Tendon gallery 8. Incore tunnel 9. Sumps

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No. R104P-5.2	Title: Containment	
Written by: Gibson	Approved by:	Date:2/94

4.1.4 Containment Penetrations

1. Electrical and Piping Penetrations
   (a) double barrier, volume between barriers pressurized greater than design pressure.
2. Equipment hatch
   (a) double gasket, dished, large enough for vessel o-ring seal
3. Personnel and auxiliary hatches (Figure 5.2-3)
   (a) double doors, interlocked to prevent both open
   (b) one may be part of equipment hatch
4. Fuel Transfer Tube (Figure 5.2-4)
   (a) 20" pipe in a 24" sleeve
   (b) double gasket blind flange inside containment
   (c) isolation valve at spent fuel pit end
   (d) bellows expansion joints on both ends

4.1.5 Containment Cooling & Atmosphere Control Systems

* Control containment temperature and pressure during normal operations.

* Provide localized area ventilation for equipment inside containment.

1. Reactor Containment Fan Coolers (Normal Operation) (Figure 5.2-5, Figure 5.2-10)
   a. 5 units
   b. 2 speed fan. Normal operation in fast speed.
   c. Normal flow through roughing filter and cooling coils (Service Water)
   d. flowpath and fan speed change on SIS

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No. R104P-5.2	Title: Containment	
Written by: Gibson	Approved by:	Date:2/94

2. Purge and Exhaust System
    a. Provides continuous access (40 hrs/week) three hours after shutdown
    b. Supply is filtered and heated (40,000 CFM)
    c. Exhaust through HEPA and charcoal filters
    d. Double isolation on all connections, inside & outside.Butterfly valves.
    e. Valves close and fans trip on high radiation or ESF actuation (ϕA).
    f. Limited operation (1000 hrs/yr)

3. Containment Activated Charcoal Filter Units
    a. 2 units.
    b. HEPA and charcoal filters and fan
    c. 2 units operating 32 hours gives 2 hours of access at full power.

4. Reactor Cavity and Excore Instrumentation Ventilation
    a. 2 fans between containment wall and crane wall.
    b. Discharge into 8 ducts to excore cavities and into gap between shield and reactor vessel.

5. Control Rod Drive Mechanism Ventilation
    a. 4 booster fans (1/3 capacity each) direct air toward CRDM shroud.
    b. 2 fans (full capacity each) induce flow from shroud to upper containment volume.

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No. R104P-5.2	Title: Containment	
Written by: Gibson	Approved by:	Date:2/94

Figure 5.2-6,7,8

4.1.6 Containment Spray System

* Protect the containment barrier and minimize the leakage of radioactivity to the environment following an accident by reducing containment temperature and pressure.

* Limit offsite radiation levels to < Part100 limits

* Remove radioactive iodine from containment atmosphere after LOCA

1. System Description
   a. Two independent subsystems except common spray additive tank.
   b. Suction from RWST during injection phase, from sump during recirculation phase.
   c. Eductors in bypass lines for NaOH addition to remove iodine from containment atmosphere.
   d. Discharge to ring headers inside dome.
   e. System starts on high high containment pressure.

4.1.7 Containment Isolation

1. Containment integrity
   (a) Non-automatic valves and blind flanges closed.
   (b) Equipment hatch closed.
   (c) One door of each personnel hatch closed.
   (d) Automatic valves operable or deactivated in closed position, or if inoperable another valve in line is closed.
   (e) TS requirements for leak testing are satisfied.
   (f) Required in Modes 1-4 and 6 when fuel moved.

2. Phase A
   (a) ESFAS or manual
   (b) isolates most non-ESF penetrations

3. Phase B
   (a) High High (Hi-3) Containment Pressure
   (b) isolates remainder of non-ESF penetrations (Component Cooling to RCP's)

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No. R104P-5.2	Title: Containment	
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4. Containment Purge Isolation
   (a) Close valves, shut off fans

5. Main Steam Line Isolation
   (a) Primarily for MSLB

6. Main Feedwater Isolation
   (a) Signals = SIS, P-4 + low Tavg, Hi SG level

4.1.8 Combustible Gas Control Systems

1. Post-accident hydrogen can come from:
   (a) Zirconium - water reaction
   (b) Radiolytic decomposition of water
   (c) Chemical reaction of containment materials
   (d) Dissolved hydrogen coming out of solution

Figure 5.2-10

2. Hydrogen Purge System
   (a) Used when no other way of removing hydrogen exists.
   (b) Exhaust consists of fans, ductwork, pre-filter, HEPA filter, charcoal filter. Supply may have fans and ductwork.

3. Hydrogen Monitoring (Sampling) System

4. Hydrogen Mixing Fans
   (a) Prevent stagnant areas

Figure 5.2-9

5. Hydrogen Recombiners
   (a) Internal or external
   (b) Air heated by electric heaters
   Recombination of Hydrogen & Oxygen = Water

5.0 Review

5.1 Learning Objectives

5.2 Answer Questions

5.3 AUXILIARY FEEDWATER SYSTEM

Learning Objectives:

1. State the purposes of the auxiliary feedwater system.
2. Describe the decay heat removal flowpath following a reactor trip under the following conditions:
   a. With off-site power available and
   b. Without off-site power available.
3. List the suction sources for the auxiliary feedwater pumps and under what conditions each suction source is used.

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No. R104P-11A	Title:Auxiliary Feedwater System	
Written by:Gibson	Approved by:	Date: 9/92

1.0 Special Instructions & Training Aids

1.1 Figure 5.3-1

2.0 References

2.1 W PWR Technology Manual, Chapter 5.3
2.2 Callaway FSAR
2.3 Callaway/Wolf Creek Drawings
2.4 Westinghouse Training Manual, NPS 223

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No. R104P-11A	Title:Auxiliary Feedwater System	
Written by:Gibson	Approved by:	Date: 9/92

Objectives Viewgraph	**3.0 Objectives** 3.1 State the purposes of the AFW system. 3.2 Describe the decay heat removal flowpath following a reactor trip under the two conditions listed: a. With offsite power available. b. Without offsite power available 3.3 List all suction sources for the AFW pumps and under what conditions each suction source is used.
	4.0 Presentation
Purposes Page 5.3-1	**4.1 Purposes** a. Provide feedwater to the steam generators to maintain a heat sink for the following conditions. *Loss of main feedwater *Unit trip and loss of offsite power *Small break loss of coolant accident b. Provide a source of feedwater during plant startup and shutdown

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No. R104P-11A	Title:Auxiliary Feedwater System	
Written by:Gibson	Approved by:	Date: 9/92

	4.2 System Description
Overview Figure 5.3-1	4.2.1 Suction sources a. Condensate Storage Tank (Normal) b. Service Water *if CST empty *if CST is not seismic
	4.2.2 Two electric pumps a. each pump supplies two S/G's b. each powered from separate ESF bus c. one pump to 2 S/G sufficient to cool RCS for RHR
	4.2.3 One turbine driven pump a. supplies all S/G's b. steam supply available from two S/G's
Auto Start Signals	4.2.4 Automatic Start Signals a. Motor driven pumps *Low low level in any one S/G *Loss of both MFPs b. Turbine & Motor driven pumps *Low low level in 2 or more S/Gs *ESF signal *Loss of offsite power (Note: sensed as undervoltage on 4.16 KV buses)
(Note: On Figure, but not discussed in manual, only cover if asked.)	4.2.5 Level Control Valves a. 8 valves - 2 per S/G b. 4 valves from motor pumps - 4 valves from turbine pump c. Valves are air operated, automatically controlled based on S/G level, motor operated bypass valves used if air is lost. d. Pressure Interlock Valves (Sequoyah- for water hammer considerations, valve is closed when pump startsuntil pressure builds up, then valve opens. Other plants use cavitating venturis.)

WESTINGHOUSE TECHNOLOGY LESSON PLAN

Lesson No. R104P-11A	Title:Auxiliary Feedwater System	
Written by:Gibson	Approved by:	Date: 9/92

4.3 System Features

This discussion is not in the manual. Answers L.O. #2.

4.3.1 Loss of main feedwater

a. reactor trips on low low S/G level
b. AFW supplies feedwater to S/Gs for heat sink
c. Steam dumps remove excess heat input
d. RCPs provide forced circulation of RCS
e. Decay heat removal same for any reactor trip with offsite power available - see 4.3.2 for comparison.

4.3.2 Loss of offsite power from full power

a. RCPs no power, reactor trips on low RCS flow, natural circulation established
b. Circulating water pumps no power, condenser not avail able, Steam dumps N/A
c. Feed with AFW, Steam out S/G PORVs or safeties for decay heat removal

4.3.3 Small Break LOCA

a. Break flow (i.e. ECCS flow) not enough to remove core decay heat
b. S/G heat sink important for decay heat removal
c. Contrast to large LOCA

4.3.4 Plant Startup and Shutdown

a. Main feed too much capacity for low power usage
b. Use AFW below ~2% power

Review Objectives Viewgraph

5.0 Review Learning Objectives

5.4 COOLING WATER SYSTEMS

Learning Objectives:

1. Sate the purpose of the component cooling water system.

2. List two component cooling water system loads.

3. Explain how the component cooling water system is designed to prevent the release of radioactivity to the environment.

4. State the purpose of the service water system.

5. List two service water system loads.

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No. R104P-11C	Title: Cooling Water Systems	
Written by:Gibson	Approved by:	Date: 9/92

1.0 Special Instructions and Training Aids

1.1 Chapter 5.4Viewgraphs

1.2 This chapter does not distinguish between Essential Service Water and a non-safety Service Water. The Service Water System described in this chapter does both functions.

1.3 Condenser Circulating Water is covered, but there are no objectives for the system.

2.0 References

2.1 W Technology Manual Chapter 5.4

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No. R104P-11C	Title: Cooling Water Systems	
Written by:Gibson	Approved by:	Date: 9/92

3.0 Objectives

3.1 State the purposes of CCW
3.2 List twoCCW loads.
3.3 Explain how the design of CCW prevents the release of radioactivity to the environment
3.4 State the purposes of SW
3.5 List two SW loads.

CCW Purposes
Page 5.4-1

4.0 Presentation

4.1 Component Cooling Water

4.1.1 Purposes

a. Remove heat from system and components which contain radioactive water.
b. Provide cooling for Engineered Safety Features systems and components.
c. Provides a barrier between radioactive systems and the environment.

Figure 5.4-1
CCW Design

4.1.2 Description

a. Two safety related loops - independent and redundant.
b. One service loop - from either safety loop.
c. Seismic Category I,Class 1E electrical power. Design 150psig, 200°F
d. Three (100% capacity) pumps, three heat exchangers and a surge tank
e. CCW low pressure system-leakage from loads or cooling INTO CCW.

Loads

f. Safety related loads include:
   1. RHR heat exchangers
   2. RHR pumps
   3. SI pumps
   4. Charging Pumps
   5. RCP motors and TBHX (φB)
   6. Letdown heat exchanger
   7. Excess Letdown heat exchanger (φA)
   8. Seal Water heat exchanger
   9. Spent Fuel Pit heat exchanger
   10. Sample heat exchangers
   11. Reactor Vessel Support cooling

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No. R104P-11C	Title: Cooling Water Systems	
Written by:Gibson	Approved by:	Date: 9/92

12. Boric Acid Evaporator condensers
13. Waste Gas Compressors
14. High Temperature Containment Penetrations

g. Surge tank
1. baffle
2. vented to aux. bldg. -closes on hi rad.
3. high level - inleakage
   low level - system breech

j. Operation
1. Normally two pumps running
2. ESF starts A & B pumps - C will start if A or B does not.
3. CIS ϕB will isolate all service loads in containment.
4. Leak detection provided by surge tank level changes and rad monitor on pump suction

Service Water Purpose
Page 5.4-1

Figure 5.4-2

4.2 Service Water

4.2.1 Purpose -

a. Provides heat sink for all non-radioactive plant equipment EXCEPT the Main Condenser

4.2.2 Description

a. Three pumps take suction on ultimate heat sink
b. Seismic, 2 trains - physical and electrical separation
c. Loads supplied

Loads

1. Component Cooling heat exchangers
2. Containment fan coolers
3. Diesel generator coolers
4. Control Room A/C condensers
5. Aux. Bldg. ventilation cooling coils
6. Auxiliary Feedwater Pumps emergency supply

d. Operation
1. Normally two pumps running,third in standby.
2. All three start on ESF

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No. R104P-11C	Title: Cooling Water Systems	
Written by:Gibson	Approved by:	Date: 9/92

Circc. Water Purpose Page 5.4-2	**4.3 Condenser Circulating Water** 4.3.1 Purpose a. Provide cooling water to main turbine condenser tubes and acts a heat sink for thr turbine and steam dump systems 4.3.2 System Description a. Three pumps (weather temp, condenser ΔT) b. Screens c. Thru condenser tubes d. Outlet to discharge pond
Review ObjectivesVugraph	**5.0 Review Learning Objectives**

6.0 ELECTRICAL SYSTEMS

Learning Objectives:

1. List the purposes of the plant electrical systems.

2. Explain how the plant electrical system is designed to ensure reliable operation of equipment important to safety with emphasis on the following:

   a. Redundancy,
   b. Separation (physical and electrical),
   c. Reliable control power,
   d. Reliable instrumentation power, and
   e. Reliable AC power.

3. List the normal and emergency power sources to the vital (Class 1E) AC electrical distribution system.

4. State the purpose of the diesel generators.

6. Describe the automatic actions that occur in the electrical system following a plant trip and loss of off-site power.

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No. R104P-11B	Title: Electrical Systems	
Written by:Gibson	Approved by:	Date: 9/92

1.0 Special Instructions and Training Aids

1.1 Viewgraph 6-1

2.0 References

2.1 W PWRTechnology Manual, Chapter 6.0

2.2 Callaway Nuclear Station FSAR, Chapter 8.0

2.3 Westinghouse SNUPPS Electrical System Manual

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No. R104P-11B	Title: Electrical Systems	
Written by:Gibson	Approved by:	Date: 9/92

Objectives Viewgraph	**3.0 Objectives** 3.1 State the purposes of the electrical system. 3.2 Explain how the plant electrical system is designed to ensure reliable operation of equipment important to safety with emphasis on the following: a. Redundancy b. Separation (physical and electrical) c. Reliable control power d. Reliable instrumentation power e. Reliable AC power 3.3 List the normal and emergency power sources to the vital (Class 1E) AC electrical distribution system. 3.4 State the purpose of the diesel generators. 3.6 Describe the automatic actions that occur in the electrical system following a plant trip and loss of offsite power.
	4.0Presentation
Purposes Page 6-1	**4.1 Purposes:** a. Provide a reliable source of electrical power to plant systems important to safety. b. Provide a connection to the offsite distribution system (grid). c. Provide a source of power to systems for normal plant operation (non-safety systems).

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No. R104P-11B	Title: Electrical Systems	
Written by:Gibson	Approved by:	Date: 9/92

Overview Figure 6-1	**4.2 Electrical Distribution System Description** 4.2.1 Discuss plant system differences and generic features. a. High voltage, offsite distribution b. High voltage, and medium voltage, onsite distribution c. Low voltage, control and instrumentation distribution 4.2.2 Discuss redundancy and separation and point out examples of each throughout lecture. 4.2.3 Main Distribution System a. Main Distribution System b. 500kV switchyard, ring bus 4.2.4 Main Generator a. power to Main Transformer to grid b. power to non-vital equipment thru unit aux. transformer 4.2.5 Service Power System a. power from main generator /UAT b. fast transfer to offsite/System Aux. Transformer c. 480V Service Power Subsystem d. 4160 V Non-vital buses power 4160 V Vital buses
Vital Power	4.2.6 Vital Power System
4160 VAC	a. 4.16KV Vital Power Subsystem 1. Explain alternative methods ofsupplying power to vital buses (i.e., either from the output of the main generator during station operation, from offsite, or from diesels)
480 VAC	b. 480 V Vital Buses *battery chargers & smaller loads
125 VDC	c. 125V DC Control Buses *4 buses *battery chargers from 480V buses *vital batteries *breaker controls & dc control power

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No. R104P-11B	Title: Electrical Systems	
Written by:Gibson	Approved by:	Date: 9/92

120 VAC	d. 120V AC Instrumentation Buses *4 buses *RPS and ESF channels *inverter/auctioneer *125V DC or 480/120V transformer *directly from 480/120V transformer *diesels/batteries
Diesel Generators	4.2.7 Diesel Generators a. Design Criteria *up to speed and voltage in 10 secs. *fully loaded in 30 secs. b. Plant trip & loss of offsite power *no power to 4160 non-vital buses *diesels auto start *loads stripped *diesel breaker closes repowering 4160 vital buses *loads sequenced on
Review Objectives Vugraph	**6.0 Review** 6.1 Learning Objectives

7.1 MAIN AND AUXILIARY STEAM SYSTEMS

Learning Objectives:

1. State the purposes of the main steam system.

2. Identify the portion of the main steam system that is Seismic Category I.

3. State the purpose of the components and connections located in the Seismic Category I portion of the main steam system:

   a. Steam generator,
   b. Flow restrictor,
   c. Power operated relief valve,
   d. Code safety valves,
   e. Steam supply to auxiliary feedwater pump turbine,
   f. Main steam isolation valves, and
   g. Main steam check valves.

4. State the purpose of the following components associated with the main steam system:

   a. Turbine throttle/governor valves,
   b. High pressure turbine,
   c. Moisture separator reheater,
   d. Turbine intercept/reheat stop valves,
   e. Low pressure turbine, and
   f. Condenser.

WESTINGHOUSE TECHNOLOGY LESSON PLAN

Lesson No. R104-6A	Title: Main Steam and Auxiliaries	
Written by: Gibson	Approved by:	Date: 10/92

1.0Special Instructions and Training Aids

1.1 Vugraphs 7.1-1thru 3

2.0References

2.1 W PWR Technology Manual, Chapter 7.1
2.2 Callaway FSAR, Sequoyah FSAR
2.3 Callaway/Wolfcreek drawings
2.4 W Training Manual NPS-223

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No. R104-6A	Title: Main Steam and Auxiliaries	
Written by: Gibson	Approved by:	Date: 10/92

Objectives
Viewgraph

3.0 Objectives

3.1 Main Steam

1. State the purpose of the Main SteamSystem.
2. Identify the portion of the MS System that is Seismic Category I.
3. *(List in the proper flowpath order and) State the purpose of the components and connections located in the Seismic Category 1 portion of the MSS:
   a. Steam Generator
   b. Flow Restrictor
   c. Power Operated Relief Valve (PORV)
   d. Code Safety Valves
   e. Steam supply to auxiliary feed pump (AFP) turbine
   f. Main Steam Isolation Valves (MSIV)
   g. Main Steam Check Valves

4. *(List in the proper flow path order and) State the purpose of the following components associated with the Main Steam System:
   a. Turbine Throttle/Governor Valves
   b. High Pressure Turbine (HPT)
   c. Moisture Separator Reheater (MSR)
   d. Turbine Intercept/Reheat Stop Valves
   e. Low Pressure Turbine (LPT)
   f. Condenser

***Note: Don't need to know flowpath order.**

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No. R104-6A	Title: Main Steam and Auxiliaries	
Written by: Gibson	Approved by:	Date: 10/92

Purposes Page 7.1-1	**4.0 Presentation** 4.1 Purposes 1. Transfer the steam from the steam generators to the turbine generator and auxiliaries. 2. Provide overpressure protection for the steam generators. 3. Provide a path for decay heat removal.
Figure 7.1-1	4.2 System and Component Descriptions 4.2.1 Four S/G's a. 15 million lbm/hr steam flow
Focus on purposes of components and flowpaths.	4.2.2 Piping from each S/G a. ~30 in. diameter b. flow restrictor c. PORV d. 5 code safety valves e. MSIV *hi stm flow + lo stm pres or lo lo Tavg *hi hi cntmt pres f. check valves
	4.2.3 Aux feed pump from 2 S/G's
Figure 7.1-2 Focus on purposes of components and flowpaths.	4.2.4 Common header a. H.P. turbine with throttle/governor valves b. steam dump valves to condenser c. MFP's d. feedwater heaters e. MSR second stage reheat f. Aux steam reboiler g. gland seal h. L.P. turbine with intercept/reheat stop valves

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No. R104-6A	Title: Main Steam and Auxiliaries	
Written by: Gibson	Approved by:	Date: 10/92

Safety Req'ts.	4.2.5 Safety requirements a. first piping restraint downstream of MSIV back to S/G shell is Seismic Category 1. b. measured steam flow has control and safety related functions c. S/G safety and relief valves d. steam supply to turbine-driven aux feed pump
Figure 7.1-3	e. flow restrictor
Cover if time permits.	4.3 Auxiliary Steam System 4.3.1 Loads a. Plant heating b. AFW turbine pump testing c. MFP turbine testing d. Storage Tank heating e. Main Turbine sealing steam f. Main condenser sparging g. Decontamination stations h. Domestic hot water heater i. MSR tube blanket j. Waste water processing (evaporators) 4.4.2 Auxiliary Steam Reboiler a. U-tube HX b. Heated by main steam from bypass header or 5th stage extraction steam 4.4.3 Auxiliary Steam Boiler (Oil Fired) a. Used when Main or Extraction steam not available
Review ObjectivesVugraph	**5.0 Review Learning Objectives**

7.2 CONDENSATE AND FEEDWATER SYSTEM

Learning Objectives:

1. List the purposes of the condensate and feedwater system.

2. State the purpose of the components and penetrations in the Seismic Category I portion of the main feedwater system:

   a. Main feedwater isolation valves,
   b. Auxiliary feedwater system penetrations, and
   c. Main feedwater check valves.

3. State the purpose of the following condensate and feedwater system components:

   a. Main condenser,
   b. Hotwell,
   c. Condensate (or hotwell) pumps,
   d. Condensate demineralizers (polishers),
   e. Low pressure feedwater heaters,
   f. Main feedwater pumps,
   g. High pressure feedwater heaters,
   h. Feedwater control and bypass valves, and
   i. Steam generators.

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No. R104P-6B	Title: Condensate and Feedwater	
Written by: Gibson	Approved by:	Date: 10/92

1.0Special Instructions and Training Aids

1.1 Vugraphs 7.2-1thru 5

2.0References

2.1 W PWRTechnology Manual, Chapter 7.2
2.2 Callaway FSAR, Sequoyah FSAR
2.3 Callaway/Wolfcreek drawings
2.4 W Training Manual NPS-223
2.5 Tech. Spec. Pages 3/4 7-6 and 7

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No. R104P-6B	Title: Condensate and Feedwater	
Written by: Gibson	Approved by:	Date: 10/92

3.0 **Learning Objectives**

1. List the purposes of the Condensate and Feedwater System.

2. State the purpose of the components and penetrations in the seismic Category I portion of the Main Feedwater System:
   a. Main Feedwater Isolation Valves (MFIV)
   b. Auxiliary Feedwater (AFW) System penetrations
   c. Main Feedwater Check Valves

3. *(List in proper flowpath order and) State the purpose of the followingCondensate and Feedwater System components:
   a. Main Condenser
   b. Hotwell
   c. Condensate (hotwell) pumps
   d. Condensate Demineralizers (Polishers)
   e. Low pressure feedwater heaters
   e. Main feed pumps (MFP)
   f. High pressure feedwater heaters
   g. Feedwater control and bypass valves
   h. Steam generators

***Don't need to know flowpath order.**

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No. R104P-6B	Title: Condensate and Feedwater	
Written by: Gibson	Approved by:	Date: 10/92

	4.0 Presentation
Purposes Page 7.2-1 Figure 7.2-1	**4.1 Purposes - Condensate & Feedwater System** 1. Transfer and preheat water from main condenser to S/G's. 2. Collect and distribute heater drains. 3. Purification and secondary chemistry control.
Figure 7.2-2 (Leave on #1 projector while discussing other components.) #2 projector Figure 7.2-3	**4.2 System Description - Condensate System** 4.2.1 Main Condenser a. Heat sink b. Storage reservoir c. Common header connects the three hotwell sections. d. L.P. heater train located inside neck of condenser. e. Pressures: L.P. shell - 27.9 "Hg; IP shell - 27.35 "Hg; HP shell - 26.9 "Hg; hotwell - 26.4 "Hg. f. Hotwell level control Makeup/Divert(Reject)
On #1 projector (Figure 7.2-2)	4.2.2 Condensate Pumps a. Threepumps;ninestage,vertical, centrifugal; 3,000 HP motors. b. Nominal capacity - 33%. Emergency capacity - 50%. 4.2.3 Demineralizer System a. Six deep bed demineralizers (H-OH) b. One bed for each 20% power d. Recirc mode during startup to remove suspended solids e. Demin. may be bypassed.

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No. R104P-6B	Title: Condensate and Feedwater	
Written by: Gibson	Approved by:	Date: 10/92

#2 projector
Figure 7.2-4

4.2.4 Low Pressure Feedwater Heaters
- a. Three 50% trains of four heaters.
- b. Straight tube type
  1. Heating is by extraction steam from L.P. turbines.
  2. Cascading heater drains
  3. Temperature rises from 126°F to 318°F.
  4. Efficiency gain of 15%.
- c. Heaters are located inside neck of main condensers.
  1. Saves on space and insulation.

#1 projector
Figure 7.2-5

4.3 Feedwater System

4.3.1 Preheats, pressurizes, and transportsfeedwater from main condensate system to S/G's.
- a. Combines condensate and feed heater drains.

4.3.2 Main Feedwater Pumps
- a. Two pumps; turbine driven, centrifugal
- b. Variable capacity up to 17,650 gpm
- c. Suction sources
  1. Condensate system
  2. Heater Drain system via heater drain pumps

4.3.3 High Pressure Feedwater Heaters
- a. Two 50% trains of three heaters
- b. U-tube type heat exchangers
  1. Temperature rises from 333°F to440°F.
  2. Heating isby extraction steam from H.P. turbine.
  3. Cascaded heater drains
  4. One train may be isolated and bypassed.

4.3.4 Headers combine leaving the feed heaters,then divide into four lines to S/G's.
- a. Feedwater Control Valve
  1. Used to control flow above 15% power.
  2. 14 " valves

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No. R104P-6B	Title: Condensate and Feedwater	
Written by: Gibson	Approved by:	Date: 10/92

3. SGWLCS - Chapter 11.1

b. Feedwater Control Bypass Valve
   1. Used to control flow below 15% power.
   2. 6 inch.

c. Main Feed Isolation Valve
   1. Seismic Category I
   2. Shut automatically on
      a. High S/G level
      b. Safety Injection Signal (SIS)
      c. A reactor trip
      d. S/G lo-lo level

e. Auxiliary Feedwater Connection

Review
ObjectivesVugraph
Figure 7.2-2
Figure 7.2-5

5.0 Review

5.1 Condensate System

5.2 Feedwater System

8.0 ROD CONTROL SYSTEM

Learning Objectives:

1. State the purpose of the rod control system.
2. Briefly explain how each purpose is accomplished.
3. List the inputs into the automatic rod control system and the reason each input is necessary.
6. Describe both the individual (analog) and the group demand rod position indication.

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No. R104P-9	Title: Rod Control System	
Written by: Gibson	Approved by:	Date:12/93

1.0 Special Instructions and Training Aids

1.1 The student must be familiar with the systems to be able to analyze subsequent transients.

1.2 Vugraphs 8-1 thru 5.

2.0 References

2.1 Westinghouse Technology Manual, Chapter 8
2.2 Westinghouse Technical Manual
2.3 Instructor Guide
2.4 Westinghouse Training Manual

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No. R104P-9	Title: Rod Control System	
Written by: Gibson	Approved by:	Date:12/93

3.0 Objectives

1. State the purpose of the Rod Control System.
2. Briefly explain how each purpose is accomplished.
3. List the inputs into the Automatic Rod Control System and the reason each input is necessary.

6. Describe both the individual (*analog and digital) and the group demand rod position indication systems.

   *only need to know <u>analog</u>

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No. R104P-9	Title: Rod Control System	
Written by: Gibson	Approved by:	Date:12/93

	4.0 Presentation - Rod Control
	4.1 Purposes
	1. Provide manual positioning of the control rods for startup, shutdown, and power operations.
Figure 8-2	2. Automatically position the control rods to maintain programmed Tavg during power operation by regulating reactivity within the core.
	4.2 System Design
Use boron\xenon/ load change and Fig.8-2 to explain.	1. 5% per minute ramp change 2. ± 10% step change in load 3. 50% step load decrease, with 40% steam dump
	4.3 Categories and Grouping
	4.2.1 Shutdown Rods
(8-72 SPM Auto 64 SPM Manual)	1. Operated in individual bank select positions 2. Speed is preset (64 SPM) 3. No overlap, sequence is administratively controlled 4. Shutdown reactivity on rx trip 5. Four banks, 24 rods
	4.2.2 Control Rods
	1. Operated in manual, automatic, or individual bank select positions 2. Overlap and sequence in manual and auto only 3. Speed in auto is variable, preset in manual or individual bank 4. Control Tavg in power range (15-100%) 5. Four banks, eight groups, 29 rods

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No. R104P-9	Title: Rod Control System	
Written by: Gibson	Approved by:	Date:12/93

For Instructors Reference

(SNUPPS)

POWER CABINET AND CONTROL ROD DETAILS

1AC -	control bank A group 1	2 rods
	control bank C group 1	4 rods
	shutdown bank A group 1	4 rods
2AC -	control bank A group 2	2 rods
	control bank C group 2	4 rods
	shutdown bank A group 2	4 rods
1BD -	control bank B group 1	4 rods
	control bank D group 1	4 rods(2)
	shutdown bank B group 1	4 rods
2BD -	control bank B group 2	4 rods
	control bank D group 2	5 rods(3)
	shutdown bank B group 2	4 rods
SCD -	shutdown bank C	4 rods
	shutdown bank D	4 rods
	(shutdown bank E	4 rods)
	Total	53 rods

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No. R104P-9	Title: Rod Control System	
Written by: Gibson	Approved by:	Date:12/93

Figure 8-1	4.3 Detailed description 4.3.1 Inputs for automatic control 1. Temperature mismatch Tref - Tavg *Tref generated from Pimp *Tavg is highest of loop average temperatures 2. Power mismatch *Rate of change of secondary -primary power *Secondary power is from Pimp *Primary power is highest of power range nuclear instrument channels *Anticipates a change in Tavg. Rate of change makes it very responsive during a transient and unresponsive to a steady state difference.
Figure 8-3 ΔT=1.5-3.0°F 8 SPM 6.24s. betw. pulses ΔT=3.0-5°F 32/SPM/°F ΔT= ± 5°F 72 SPM 834ms.betw.pulses Deadband ±1.5oF Lockup 0.5oF	4.3.2 Summing Unit Adds temperature and power mismatches 4.3.3 Reactor Control Unit Determines rod speed and direction. Explain min, max, and proportional rod speed. Explain "deadband" and "lockup". 4.3.4 Sequence always takes 780 milliseconds. Rod speed is varied by changing the time between steps. One step = 5/8 inch rod motion.
Explain startup sequence. Page 8-3.	4.3.5 Bank Selector Switch Individual Bank Select (SB A,B,C,D;CB A,B,C,D) Manual Automatic

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No. R104P-9	Title: Rod Control System	
Written by: Gibson	Approved by:	Date:12/93

4.3.6 CRDM Power Supply

1. 2 Motor-Generator sets
2. Powered from non-vital 480 v buses
3. Power cabinets convert ac to pulsed dc for CRDM coils
4. 2 series Reactor trip breakers

Figure 8-4

4.3.7 CRDM

1. Description
   Coils and latches
   RCS pressure boundary

2. Rod Movement Sequences
   Begins an up or down sequence sent to power cabinets when signal sent from master cycler.

   Out Sequence
   1. Movable gripper on
   2. Stationary gripper off
   3. Lift coil on
   4. Stationary gripper on
   5. Movable gripper off
   6. Lift coil off

   In Sequence
   1. Lift coil on
   2. Movable gripper on
   3. Stationary gripper off
   4. Lift coil off
   5. Stationary gripper on
   6. Movable gripper off

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No. R104P-9	Title: Rod Control System	
Written by: Gibson	Approved by:	Date:12/93

4.0 Presentation - IRPI

4.1 Purposes

1. Provide continuous indication of actual and demanded control rod position.

2. Provide info to plant computer.

3. Provide alarms for improper rod alignments.

4.2 General Description

4.1.1 Methods of Indication

1. Bank Demand
   Assumes rod movement
2. Individual
   Analog or Digital
   Measures actual position

4.3 Detailed Description

4.2.1 Bank demand

1. Signal from control system
2. Group and bank information
3. Digital step counter on MCB

Figure 8-5

4.2.2 Analog Individual Rod Position Indication

1. Variable Linear Transformer
   a. Outside rod drive shaft housing
   b. Primary Coil (15 vac)
   c. Secondary Coil (8-12.5 vac)
   d. Coupling increased by drive shaft
   e. Measures 0-230 steps
   f. Accuracy 5% (11.5 steps)
   g. Output to signal conditioning module

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No. R104P-9	Title: Rod Control System	
Written by: Gibson	Approved by:	Date:12/93

2. Signal Conditioning Module
   a. One per rod
   b. Rectifies input to DC (8-12.5 vac)
   c. Calibrates rod position
   d. Outputs
      1. rod position meter
      2. rod bottom light via bistable
      3. computer

3. Rod bottom/rod drop alarm
   a. <20 steps actuation

5.0 Review

9.0 EXCORE NUCLEAR INSTRUMENTATION

Learning Objectives:

1. List and state the purposes of the three ranges of excore nuclear instrumentation.

2. Concerning the excore nuclear instrumentation inputs into the reactor protection system:

   a. List the reactor protection system inputs from the excore nuclear instrumentation and
   b. State the purpose of each input.

3. Explain how the excore nuclear instrumentation is capable of detecting both axial and radial power distribution.

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No. R104P-8	Title: Excore Nuclear Instrumentation	
Written by: Gibson	Approved by:	Date:12/93

1.0 Special Instructions and Training Aids

1.1 Emphasis should be placed on system inputs to the RPS and control systems to ensure that students can analyze subsequent transients and instrument failures.

1.2 Vugraphs 9-1 thru 7.

2.0 References

2.1 W PWR Technology Manual Chapter 9
2.2 Callaway FSAR
2.3 Westinghouse Technology Manual (Nuclear Instrumentation System)
2.4 Technical Specifications

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No. R104P-8	Title: Excore Nuclear Instrumentation	
Written by: Gibson	Approved by:	Date: 12/93

3.0 Objectives

3.1 List and state the purposes of the three ranges of Excore Nuclear Instrumentation.

3.2 Concerning the Excore Nuclear Instrumentation inputs into the Reactor Protection System:

a. List the Reactor Protection System inputs from the Excore Nuclear Instrumentation System.

b. State the purpose of each input.

3.3 Explain how the Excore Nuclear Instrumentation is capable of detecting both axial and radial power distribution.

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No. R104P-8	Title: Excore Nuclear Instrumentation	
Written by: Gibson	Approved by:	Date:12/93

4.0 Presentation

4.1 The purposes of the excore nuclear instrumentation system are as follows:

1. Provide indication of reactor power from shutdown to full power conditions.
2. Provide inputs to the Reactor Protection System during startup and power operation.
3. Provide reactor power information to the Automatic Rod Control System.
4. Provide axial and radial power distribution information during power operations.

4.2 General Design Criteria

1. Must accurately measure flux over a wid range(12 decades).
2. Must provide continuous monitoring with no "blind spots".
   a. Overlap between ranges
   b. Redundant channels in each range
3. Channel independence and separation
   a. Separate vital power supplies, cable runs and cabinets
   b. Protective functions isolated from controls
   c. 2 source, 2 intermediate, 4 power range channels

Figure 9-1

4.3 Division of Ranges

1. Source range
   a. 6 decades
   b. Shutdown, startup monitoring

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No. R104P-8	Title: Excore Nuclear Instrumentation	
Written by: Gibson	Approved by:	Date:12/93

2. Intermediate Range

   a. 8 decades
   b. From top of source range to top of power range.

3. Power Range
   a. 3-1/2 decades
   b. "At power" monitoring

4.4 Detector Locations

Figure 9-2

1. In wells against outside of vessel

2. 6 wells used

   a. Each power channel has its own well located 90° apart at corners, 2 detectors per well

   b. Source range detectors at 1/4 core height, at core flats (near sources).

   c. Intermediate range at 1/2 core height, in same well as a source detector.

4.5 Source Range

Detector Theory
BF_3 Figure 9-3

Uses
Figure 9-6

1. 2 channels - BF_3 detector - Explain theory of operation.

2. Sensitive at very low flux levels (10^0 - 10^6 cps)

3. Pulse output proportional to leakage flux

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No. R104P-8	Title: Excore Nuclear Instrumentation	
Written by: Gibson	Approved by:	Date:12/93

4. Signal Conditioning

   a. Preamplifier - increases signal/noise ratio.
   b. Pulse amplifier/discriminator - cuts off smaller gamma pulses and noise.
   c. Pulse shaper - square wave output equal to one half the input.
   d. Pulse amplifier
   e. Log pulse integrater - converts pulses to a log function. 0-10VDC output proportional to log of input.

5. Signal uses

   a. Source range hi flux trip - 10^5 cps, 1/2 protection.
      1. Protects against inadvertent startup.

   b. "Hi flux at shutdown," "Containment Evacuation" alarms - 1/2 decade above background (protection).

   c. Control (non-protection) signal use
      1. Via isolation amp - separates protective and control portions of system
      2. Flux level meter on control panel logmeter 1 - 10^6 cps
      3. S.U.R. in dpm on control panel located next to level meter
      4. Flux level recorder - NR45 select one or both source ranges

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No. R104P-8	Title: Excore Nuclear Instrumentation	
Written by: Gibson	Approved by:	Date: 12/93

Detector Theory CIC Figure 9-4 *Uses* Figure 9-6	4.6 Intermediate Range 1. Two channels - compensated ion chambers -explain theory of operation 2. Range from top of source range to 120% power 10^{-11} amps to 10^{-3} amps 3. Log current amplifier - amplifies signal - output 0-10VDC - proportional to log of input 4. Signal uses: a. Source range trip block permissive(P-6)(protection)1/2 b. IR hi flux trip (protection) 1. 1/2, current equivalent to 25% full power 2. Protects against inadvertent startup c. IR hi flux rod withdrawal stop (protection) 1. 1/2, current equivalent to 20% full power 2. Prevent hi flux trip 3. Prevented when hi flux trip is blocked d. Control (non-protective) signal uses: 1. Via isol amp for separation 2. Flux level meter on control board logmeter 10^{-11} - 10^{-3} amps 3. Flux level recorder on control board NR45 Select one or both ranges 4. S.U.R. in dpm on control board located next to level recorder

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No. R104P-8	Title: Excore Nuclear Instrumentation	
Written by: Gibson	Approved by:	Date:12/93

Detector Theory
UIC Figure 9-5

Uses
Figure 9-7

4.7 Power Ranges

1. 4 channels, uncompensated ion chambers - Explain theory of operation

2. Current output proportional to leakage flux

3. Signal development

   a. Two detectors/channel - upper and lower

   b. Each detectors output thru range selector switch
      Selected per detector current on local meter

   c. Individual detector output functions
      1. Each isolation amplifier 0-10VDC proportional to power
      2. To ΔI (top - bottom) for OTΔT
      3. Δ Flux meter on control board One per channel
      4. Δ Flux recorder on control board
         NR45 - select one channel/switch
      5. To detector current comparator for quadrant power tilt alarm.

   d. Summer/Amplifier - combines individual detector outputs - gives "total power" 0-10VDC output

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No. R104P-8	Title: Excore Nuclear Instrumentation	
Written by: Gibson	Approved by:	Date:12/93

e. Combined channel protective functions:

1. Power range hi flux level trip, high setpoint - 109%, 2/4

2. Power range high flux level rod stop - 103%, 1/4
   Prevent hi flux trip

3. Positive flux rate trip +5%, 2 sec. tim const., 2/4
   Protects against rod ejection
   Loss of CRDM pressure housing

4. Negative flux rate trip -5%, 2 sec.
   Multiple dropped rods

5. Power range hi flux level, low setpoint trip
   Inadvertent startup
   25%, 2/4

6. P-8, loss of flow permissive, 35%, 2/4
   Allows 3-loop ops. if below setpoint (35%).
   Reactor trip if above setpoint
   Not allowed by OL
   May be reset to 75% after resetting certain trips (OPΔT, OTΔT)

7. P-9, reactor trip on turbine trip, 50%, 2/4

8. P-10 (intermediate and power range trips block permissive)
   Allows manual block of inter. range hi flux, trip and power range hi flux low setpoint trip
   Provides input to P-7 to "enable" the at-power trips
   Prevents energizing source range detector
   10%, 2/4

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No. R104P-8	Title: Excore Nuclear Instrumentation	
Written by: Gibson	Approved by:	Date:12/93

f. Power range combined control functions:

1. Input to rod control system
   Power mismatch circuit
   via auctioneered high circuit
2. Control board % power meter and recorder
   0-102% power
3. Over-power recorder 200%
4. Channel deviation (channel to channel)

5.0 Review

5.1 RPS feature
5.2 Control features

10.1 REACTOR COOLANT SYSTEM INSTRUMENTATION

Learning Objectives:

1. List three protection signals described in this chapter.

2. List two systems which respond to the auctioneered T_{avg} signal.

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No.R104P-04B	Title: RCS Instrumentation	
Written by:Gibson	Approved by:	Date:12/92

1.0 Special Instructions and Training Aids

1.1 This module will ensure that the student understands the primary instrument and control systems and is prepared to analyze selected transients.

1.2 Vugraphs 10-1 thru 5

2.0 References

2.1 PWR Technology Manual, Chapter 10.1
2.2 Callaway FSAR
2.3 Callaway PLS
2.4 Westinghouse Training Manual, NPS 215
2.5 SNUPPS Instrument Failure Reference Manual
2.6 Power Plant Engineering Manual

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No.R104P-04B	Title: RCS Instrumentation	
Written by:Gibson	Approved by:	Date:12/92

Objectives Objectives Vugraph	**3.0 Objectives (Section 10.1)** 3.1 List three protection signals described in this chapter. 3.2 List two systems which respond to the auctioneered T_{avg} signal.

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No.R104P-04B	Title: RCS Instrumentation	
Written by:Gibson	Approved by:	Date:12/92

	4.0 Presentation 4.1 Purposes 4.1.1 Monitor RCS temperature, pressure, flow and level (Only temperature and flow covered in this chapter). 4.1.2 Provide inputs to the Reactor Protection System (RPS) for reactor trip, engineered safety features actuation, and interlocks. 4.1.3 Provide inputs to various primary and secondary control systems.
Figure 10.1-1	4.2 Temperature 4.2.1 RTD Operation (a) platinum or nickel wire (b) resistance measurement in a bridge circuit
Figure 10.1-2	4.2.1 Narrow range RTD's (a) narrow range -530° to 630°F (b) well mounted (c) T_h - 3 RTDs per loop, 120° apart for rep. sample (d) T_c -1 RTD per loop, downstream of RCP (e) $T_{avg} = (T_{hot} + T_{cold}) / 2$; $\Delta T = T_{hot} - T_{cold}$ (f) protection, control, indication 4.2.2 Wide range RTD's (a) hot and cold legs (b) well mounted (c) input to Subcooling monitor, RVLIS, COPPS (d) 0 to 700°F

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No.R104P-04B	Title: RCS Instrumentation	
Written by:Gibson	Approved by:	Date:12/92

Figure 10.1-3 Figure 10.1-4	4.2.3 Protection Uses of $T_{avg}/\Delta T$ (a) OTΔT (T_{avg}, RCS P, $\Delta\phi$) *DNB (b) OPΔT (T_{avg}, rate of change of T_{avg}, $\Delta\phi$) *kW/ft. ; overpower *limits req'd. range for OTΔT *backup to high neutron flux trip (c) low T_{avg} = 554°F ; P-4 & low T_{avg} FW isol. (d) low-low T_{avg} = 540°F ; P-12 *steam dump interlock *high steamflow ESF block permissive
Figure 10.1-5	4.2.4 Control uses (a) Rod control system *T_{avg}/T_{ref} mismatch for rod speed & direction (b) Steam dumps *T_{avg}/T_{ref}, loss of load, controls valve opening (c) Pressurizer Level control *reference level (d) Reactivity computer (e) RIL calculator (f) Alarms
Figure 10.1-2	4.3 Elbow flow instruments 4.3.1 One high pressure tap on outside of bend, three low pressure taps on inside ofbend. Three ΔP detectors per loop. 4.3.2 Low flow trip signals - DNB protection
Review ObjectivesVugraph	**5.0 Review** 5.1 Learning Objectives

10.2 PRESSURIZER PRESSURE CONTROL SYSTEM

Learning Objectives:

1. State the purpose of the pressurizer pressure control system.
2. List all pressurizer pressure inputs to the reactor protection system and state the purpose of each input.
3. List the devices or trips that would actuate to limit or control pressure as reactor coolant system pressure increases from normal system pressure to design system pressure of 2485 psig.
4. List the devices or trips that would actuate to limit or control pressure as reactor coolant system pressure is decreased from its normal pressure of 2235 psig.

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No.R104P-04C	Title: Pressurizer Pressure Control	
Written by:Gibson	Approved by:	Date:12/92

1.0 Special Instructions and Training Aids

1.1 This module will ensure that the student understands the pressurizer pressure control system and is prepared to analyze selected transients (instrument failures).

1.2 Vugraphs 10.2-1 & 2

2.0 References

2.1 PWR Technology Manual, Chapter 10.2
2.2 Callaway FSAR
2.3 Callaway PLS
2.4 Westinghouse Training Manual, NPS 215
2.5 SNUPPS Instrument Failure Reference Manual
2.6 Power Plant Engineering Manual

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No.R104P-04C	Title: Pressurizer Pressure Control	
Written by:Gibson	Approved by:	Date:12/92

Objectives Objectives Vugraph	**3.0 Objectives (Section 10.2)** 3.1 State the purpose of the Pressurizer Pressure Control System. 3.2 List all Pressurizer Pressure inputs to the Reactor Protection System and state the purpose of each input. 3.3 List *(in order) the devices or trips that would actuate to limit or control pressure a RCS pressure increases from normal system pressure to design system pressure of 2485 psig. 3.4 List *(in order) the devices or trips that would activate to limit or control pressure as RCS pressure is decreased from its normal pressure of 2235 psig. ***Don't have to know order.**

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No.R104P-04C	Title: Pressurizer Pressure Control	
Written by:Gibson	Approved by:	Date:12/92

	4.0 Presentation
Purpose	4.1 Purpose 4.1.1 Control RCS pressure at 2235 psig, normal & transient conditions (a) ±5% per min. ramp with automatic rod control (b) ±10% step with automatic rod control (c) -50% step with automatic rod control & steam dumps
Figure 10.2-1	4.2 Pressure detectors and pressure control system 4.2.1 Pzr pressure used for control, indication, and protection (trip and ESFAS) (a) high pressure reactor trip - RCS integrity (b) low pressure reactor trip - DNBR (c) low pressure ESFAS - LOCA
	4.2.2 Pzr pressure control system (a) 4 channels, 2 selected (b) isolation amps (c) setpoint - 2235 psig (explain effects of change)
Figure 10.2-2	(d) variable heaters - 2220 to 2250 psig (e) backup heaters - 2210 psig (f) spray valves - 2260 to 2310 psig (g) relief valves - 2335 psig (interlock 2335 psig) (i) Other actions not from control system: 1. Rx trip - 2385 psig 2. Safety valves - 2485 psig 3. Rx trip - 1970 psig if Rx power >10%
Review ObjectivesVugraph	**5.0 Review** 5.1 Learning Objectives

10.3 PRESSURIZER LEVEL CONTROL SYSTEM

Learning Objectives:

1. State the purpose of the pressurizer level control system.
2. State the purpose of the pressurizer level input to the reactor protection system.
3. Identify the signal that is used to generate the "reference level" and explain why level is programmed.
4. Describe the components used to change charging flow in response to level error signals.

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No.R104P-05	Title: Chemical and Volume Control and Pressurizer Level Control Systems	
Written by:Gibson	Approved by:	Date:11/92

3.0 Objectives (Pressurizer Level Control System, Chapter 10.3)

3.1 State the purpose of the Pressurizer Level Control System.

3.2 State the purpose of the pressurizer level input to the Reactor Protection System

3.3 Identify the signal that is used to generate the "Reference Level" and explain why level is programmed.

3.4 Describe the components used to change charging flow in response to level error signals.

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No.R104P-05	Title: Chemical and Volume Control and Pressurizer Level Control Systems	
Written by:Gibson	Approved by:	Date:11/92

4.0 Presentation (Pressurizer Level Control System)

4.1 Purposes

a. Control charging flow to maintain pressurizer level within a programmed level.

b. Provide an input to the reactor protection system for RCS boundary protection

4.2 System Description

Figure 10.3-1

a. Three transmitters
   1. High level trip (backup, RCS boundary protection)
   2. Isolation amplifiers
   3. Channel selector switch
   4. Letdown isolation (minimizes RCS inventory loss)
   5. Heaters off (protect heaters)

Figure 10.3-2

b. Level program (generated from Tavg, natural expansion of RCS)
   1. Basis
      *25%- prevents the pressurizer from going dry following a reactor trip.

      *60%- prevents the pressurizer from going solid following a turbine trip from 100% power without a direct reactor trip.

Figure 10.3-1

c. Functional Description
   1. Inputs
      *Actual level
      *Reference level program
   2. Error signal (PI) controller
      a. Charging flow
         *PDP speed
         *CCP FCV position
      b. Low level deviation
      c. High level deviation
      d. Turn on BU heaters
         *preheats cooler water from hot leg on insurge

Objectives Vugraph

5.0 Review Objectives

11.1 STEAM GENERATOR WATER LEVEL CONTROL SYSTEM

Learning Objectives:

1. List the purpose of the steam generator water level control system.

2. Briefly explain how the purpose is accomplished.

3. List the reactor protection system inputs and turbine trip signals provided by the steam generator water level control instruments and the purpose of each.

4. List the inputs to the steam generator water level control system and the reason each input is necessary.

WESTINGHOUSE TECHNOLOGY LESSON PLAN

Lesson No. R104P-7A	Title: Steam Generator Water Level Control System	
Written by: Gibson	Approved by:	Date:11/93

1.0 Special Instructions and Training Aids

1.1 This module will cover the design and operation of the SGWLC system. Emphasis should be placed on the response of the system under transient conditions. Review shrink & swell. The student needs to be able to understand the control system to analyze subsequent transient.

1.2 Viewgraphs 11.1-1 & 2

2.0 References

2.1 W PWR Technology Manual, Chapter 11.1

2.2 Westinghouse Training Manuals

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No. R104P-7A	Title: Steam Generator Water Level Control System	
Written by: Gibson	Approved by:	Date:11/93

3.0 Objectives

3.1 List the purpose of the Steam Generator Water Level Control System.

3.2 Briefly explain how the purpose is accomplished.

3.3 List the Reactor Protection System inputs and turbine trip signals provided by the Steam Generator Water level control instruments and the purpose of each trip.

3.4 List the inputs to the Steam Generator Water Level Control System and the reason each input is necessary.

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No. R104P-7A	Title: Steam Generator Water Level Control System	
Written by: Gibson	Approved by:	Date:11/93

4.0 Presentation

4.1 Purpose

a. Provide automatic control of steam generator water level from 15% to 100% power.

4.2 General Description

a. Feedwater Control System
   1. Positions the 14" main feed regulating valve.
   2. Control S/G level from 15% to 100% power.
   3. Inputs
      a. Main Feedwater flow
      b. Main Steam flow
      c. SG level error

b. Feedwater Pump Speed Control System
   1. Used greater than 15% power.
   2. Maintain feed reg valve in mid-range of travel.
   3. Does not control SG level.

Not covered in chapter, but worth mentioning

c. Feedwater Bypass Control System
   1. Positions the 6" feed reg bypass valve.
   2. Control S/G level from 0% to 20% power.
   3. Uses auctioneered high nuclear power and level error.

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No. R104P-7A	Title: Steam Generator Water Level Control System	
Written by: Gibson	Approved by:	Date:11/93

Figure 11.1-1	4.3. Feedwater Control System 1. Inputs a. Pressure compensated steam flow. 1. Reason for using compensated flow b. Main feed flow 1. Reason for using SF/FF to control level c. Level Error 1. Programmed level from main turbine impulse pressure 3. Purpose of lag unit on level error Discuss shrink and swell. 2. Total error signal used to position main feed reg valve. 3. RPS Inputs - Heat Sink a. Low Low Level (in one SG) Reactor Trip b. Low Level + SF/FF Mismatch Reactor Trip 4. Turbine Trip signal a. High high SG level - for MSL & Turbine protection from moisture carryover.

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No. R104P-7A	Title: Steam Generator Water Level Control System	
Written by: Gibson	Approved by:	Date:11/93

Figure 11.1-2 *Cover if time permits.*	4.4. Feedwater Pump Speed Control 1. Inputs a. Main steam header pressure b. Main feed header pressure c. Programmed differential pressure 1. From total steam flow 2. Ramped from 45 psid to 195 psid from 0% to 100% power 2. Error between actual dp and programmed dp used to control main feed pump speed Master controller + 2 individual pump speed controllers 3. Purpose to control feedwater header pressure to maintain a constant (for a given power level) differential pressure across the MFRV => optimum valve character istics + increases pump efficiency **5.0 Review Learning Objectives**

11.2 STEAM DUMP CONTROL SYSTEM

Learning Objectives:

1. List the purposes of the steam dump control system.

3. Describe how the system functions in:

   a. Steam pressure mode and
   b. T_{avg} mode.

4. List the input signals to the steam dump control system.

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No. R104P-7B	Title: Steam Dump Control System	
Written by: Gibson	Approved by:	Date:11/93

1.0 Special Instructions and Training Aids

1.1 This module will cover the basic design and operation of the Westinghouse Steam Dump Control System (Chapter 11.2). The student must understand the design and operation of the steam dump control system to analyze subsequent transients. During presentation, emphasize operation of system during transients and affect of system malfunctions.

1.2 Vugraphs 11.2-1 thru 4

2.0 References

2.1 W PWR Technology Manual, Chapter 11.2

2.2 Westinghouse Training Manuals

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No. R104P-7B	Title: Steam Dump Control System	
Written by: Gibson	Approved by:	Date:11/93

3.0 Objectives

3.1 List the purposes of the Steam Dump System.

3.3 Describe how the system functions in:
   a. Steam pressure mode
   b. Tavg mode

3.4 List the input signals to the Steam Dump Control System.

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No. R104P-7B	Title: Steam Dump Control System	
Written by: Gibson	Approved by:	Date:11/93

	4.0 Presentation

4.1 Purposes

a. Removes stored energy and excess heat following a load rejection or reactor trip to bring Tavg to programmed value for new power level

b. Controls steam pressure at low or no-load conditions to facilitate turbine loading and provides for a manually controlled cooldown of the Reactor Coolant System.

4.2 System Description

Figure 11.2-1
Right side of Fig.

1. Steam Dump Valves (12)

2. Air Supply
   a. 100 psig
   b. 2 solenoid valves
      1. If energized, air supplied to valve, valve will open
   c. Positioner
      1. Varies air flow based on signal from I/P converter, modulates valve position

3. Solenoid Valve Interlocks
   a. DC power supply
   b. Energize to pass air

   c. Tavg > 540°F (P-12)
      1. valves won't open if Tavg ≤ 540 °F
      2. ensures no overcooling if valve fails open
      3. use bypass for 3 cooldown valves for normal cooldown below 540 °F

   d. Condenser available (C-9)
      1. One circ. pump running
      2. Vacuum in condenser
      3. For condenser protection

WESTINGHOUSE TECHNOLOGY LESSON PLAN		
Lesson No. R104P-7B	Title: Steam Dump Control System	
Written by: Gibson	Approved by:	Date: 11/93

	4. Arming signals a. Need one of 3 to complete dc circuit to solenoid valves b. One controller for use with each arming signal
	4.3 Steam Pressure Mode a. Arming signal - Selector switch in STEAM PRESS
Figure 11.2-3 Left side of Fig. *Point out to students that right side is same as 11.2-1.*	b. Inputs 1. Setpoint (man/auto station) 2. Steam header pressure c. Error signal d. I/P converter current/0-15 psig air signal e. Operations 1. Explain use for startups and cooldown
	4.4 Tavg Mode
Figure 11.2-4 Left side of Fig. *Point out to students that right side is same as 11.2-1.*	a. Arming signals 1. Loss of load 2. Reactor trip b. Inputs 1. Auctioneered High Tavg 2. Tref (P imp) FOR LOAD REJECT 3. No load set point 547°F FOR RX TRIP c. LOSS OF LOAD CONTROLLER Arming signal (>5%/min or 10% step) Tavg - Tref comparison 1. 5°F dead band 2. Allows rod control system to operate first 3. No reactor trip 4. Signal output to I/P Converter increases as ΔT increases (an vice versa) d. REACTOR TRIP CONTROLLER Arming signal (Reactor trip signal from P-4) Tavg - No load Tavg comparison 1. No dead band 2. Overrides loss of load signal

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Figure 11.3-2 Composite	**5.0 Review** - emphasize transient operation a. Modes of Operation 1. Turbine startup & loading 2. Loss of load 3. Reactor trip 4. Plant cooldown b. Arming Signals 1. Steam pressure 2. Tavg Mode a. Loss of load b. Reactor trip c. Interlocks 1. Condenser available 2. Tavg > 540°F d. Inputs 1. Main steam header pressure 2. Variable setpoint 3. Auctioneered high Tavg 4. Tref (from Pimp) 5. No load Tavg

12.0 REACTOR PROTECTION SYSTEM

Learning Objectives:

1. State the purpose of the reactor protection system.

2. Describe how the purpose of the reactor protection system is accomplished.

3. Explain and give an example of how each of the following is incorporated into the design of the reactor protection system:

   a. Redundancy,
   b. Independence,
   c. Diversity,
   d. Fail safe, and
   f. Single failure criteria.

4. Given a list of reactor trips, explain the purpose of each.

5. State the purpose of the engineered safety features actuation system.

7. List each of the five engineered safety features actuation signals and the specific accident each is designed to handle.

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Lesson No. R104P-13	Title: Reactor Protection System	
Written by: Gibson	Approved by:	Date:12/93

1.0 Special Instructions and Training Aids

1.1 The instructor must point out that some newer plants use different trip and ESF functions and setpoints.

1.2 Chapter 12 Tables and Figures

2.0 References

2.1 W PWR Technology Manual, Chapter 12

2.2 Westinghouse Technical Manuals

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3.0 Objectives

3.1 State the purpose of the RPS.

3.2 Describe how the purpose is accomplished.

3.3 Explain and give an example of how each of the following is incorporated into the design of the RPS:

a. redundancy
b. independence
c. diversity
d. fail safe

f. single failure criterion

3.4 Given a list of reactor trips, explain the purpose of each.

3.5 State the purpose of the Engineered Safety Features Actuation System.

3.7 List each of the five Engineered Safety Features Acturation Signals and the specific accident each is designed to handle.

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4.0 Presentation

4.1 Purposes of RPS

1. prevent release of radioactivity to the environment by:

   a. initiating a reactor trip if safe operating limits are exceeded.
   b. initiating ESF actuation if an accident occurs.

2. monitors, measures, compares, initiates

4.2 Design Philosophy

1. Redundancy
2. Independence
3. Diversity
4. Testability
5. Fail Safe
6. Single Failure
7. Equipment Qualification

4.3 Solid State Protection System Operation

1. Sensors
   a. 4 channels
   b. 3 used for some trips
   c. independent

2. Analog cabinets
   a. compare signal from sensor with setpoint
   b. trip bistables => input section

3. Input section
   a. 2 independent trains
   b. each recieves input from all bistables
   c. input section is relay type

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4. Logic section
   a. determines if coincidence logic is met
   b. logic section is solid state
   c. output section deenergizes UV coil for reactor trip or energizes master relay for ESF actuation.

4.4 Reactor Trip Breakers (RTB)

Two series breakers connect the MG sets to the Rod Control System.

1. Undervoltage coils

   a. RTBs are held shut by mechanical latch if UV coils are energized thru RPS.
   b. Deenergize UV coils, trips latch, breaker springs open
   c. Each RPS train controls a RTB and the opposite bypass breaker (RTBB).

4.5 Relay Outputs

Actions other than reactor trip done by energizing master relay or slaverelays.

1. ESF
2. Turbine trip on Hi SG water level
3. AFW start
4. MFW isolation . . .

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	4.6 Reactor Trips and Bases
	1. Source Range High Flux 10^5 cps, P-6 interlock, 1/2, no credit, startup protection.
Figure 12-2 Table 12-1 *Reactor Trips* and Figures 12-3 to 5 *as necessary.*	2. Intermediate Range High Flux 25%, P-10 interlock, 1/2, no credit, startup protection.
	3. Power Range Low Setpoint 25%, P-10 interlock, 2/4, startup protection.
	4. Power Range High Setpoint 109%, 2/4, overpower protection
	5. OTΔT Variable setpoint, 2/4, DNB protection setpoint calculated using Tavg, pressure and $\Delta\phi$. Tavg and pressure may raise or lower setpoint. Skewed $\Delta\phi$ lowers setpoint.
	6. OPΔT Variable setpoint, 2/4, fuel integrity (kw/ft) and backup to high flux trip. Setpoint calculated using Tavg, rate of change of Tavg, & $\Delta\phi$ Setpoint may decrease, but not increase from base.
	7. Positive Neutron Flux Rate Trip +5% with 2 second time constant, 2/4, rod ejection.
	8. Negative Neutron Flux Rate Trip -3% with 2 second time constant, 2/4, dropped rod.

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9. High Pressure
   2385 psig, 2/4, RCS integrity

10. Low Pressure
    1970 psig, 2/4, P-7 interlock, DNB protection.

11. High Level
    92%, 2/3, P-7 interlock, complement to high pressure trip.

12. Loss of Flow
    90%, 1/4 above P-8, 2/4 below P-8, P-7 interlock, DNB protection.

13. Undervoltage and Underfrequency
    56 hz or 70% volts, 2/4, P-7 interlock, DNB protection.

14. SG Level
    21% any SG, heat sink for decay heat.

15. Low Feedwater Flow
    Ws > Wf by 40% plus 25% level any SG, backup to low level trip.

16. Turbine Trip
    P-7 or P-9 interlock

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Table 12-3 *Protection Grade Interlocks*

4.7 Permissives

1. P-4
   Trip breaker open, initiates turbine trip, feedwater interlock, ESF reset logic.

2. P-6
   10^{-10} amps on IR, 1/2, allows SR block.

3. P-7
   Either P-10 or P-13 actuated, blocks and unblocks low flow trips, undervoltage and underfrequency, turbine trip (except P-9 plants), low pressurizer pressure, high pressurizer level.

4. P-8
   35% power, 2/4, changes low flow trip logic from 1/4 to 2/4.

5. P-9
   50% power, 2/4, no Rx trip on turbine trip below P-9.

6. P-10
   10% power, 2/4, input to P-7, allows block of IR and low PR flux trips, interlocks SR high voltage.

7. P-11
   1970 psig, 2/4, allows block of low pressurizer pressure ESF. On new plants, allows block of low SG pressure ESF.

8. P-12
   540°F, 2/4, allows block of high steamflow ESF, and interlocks steam dump.

9. P-13
   10% turbine power, input to P-7

10. P-14
    75% SG level any SG, trips turbine, trips feed pumps, isolates feedwater.

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Table 12-4 *Control Grade Interlocks*	4.8	Interlocks 1. C-1 20% power, 1/2, IR rod stop 2. C-2 103% power, 1/4, PR rod stop 3. C-3 3% below OTΔT trip setpoint, 2/4, rod stop and runback 4. C-4 3% below OTΔT trip setpoint, 2/4, rod stop and runback. 5. C-5 15% turbine power, auto rod withdrawal blocked below. 6. C-7 5%/minute or 10% step loss of turbine load arms steam dump. 7. C-8 Turbine trip arms steam dumps (not on P-9 plants) 8. C-9 Condenser vacuum and circulating water pumps breaker closed enables steam dump. 9. C-11 Automatic rod withdrawal of Bank D above 223 steps is blocked. 10. C-16 - not on all plants Tavg < 553°F and Tavg - Tref < 20°F stops turbine loading.

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Figure 12-6 Table 12-2 and Figures 12-7 to 10 *as necessary.*	4.9 ESF Actuation Signals 1. Low Pressurizer Pressure 1870 psig, 2/4, interlocked by P-11, LOCA 2. High Containment Pressure Backup to low pressurizer pressure and for steam break inside containment. 3. High Steamflow coincident with Low Steam Pres. or Low-low Tavg Provides protection for a break downstream of MSIV's. Closes MSIV's, interlocked by P-12. 4. Steamline Differential Pressure Steam break upstream of MSIV's. 5. Manual 2 switches 4.10 ESF Functions 1. Reactor Trip 2. Safety Injection Sequence High Head, SI, RHR 3. ϕA containment isolation 4. Auxiliary Feed 5. Main Feed Isolation 6. Diesel Generators 7. Cooling Water Systems 8. Control Room intake isolation 9. Containment Ventilation isolation 4.11 Resetting ESF 1. Timer and P-4 allows reset 2. All automatic ESF actuations are blocked, manual still allowed. 3. Closing trip breakers takes away reset, allowing automatic ESF actuation. **5.0 Review**

17.0 PLANT OPERATIONS

Learning Objectives:

1. Arrange the following evolutions in the proper order for a plant startup from cold shutdown:

   a. Start all reactor coolant pumps,
   b. Place all engineered safety systems in an operable mode,
   c. Establish no-load Tavg,
   d. Take the reactor critical,
   e. Start a main feedwater pump,
   f. Load main generator to the grid, and
   g. Place steam generator level control system in automatic.

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1.0 Special Instructions & Training Aids

1.1 This module is used to familiarize the students with the process of bringing a nuclear power plant from a cold shutdown condition to 100% power. It will provide a complete review of systems and control systems which are covered as they are addressed in the startup procedure.

1.2 Two copies of pages 4 thru 9 of the Lesson Plan are provided for use by each instructor. The figure numbers that are designated in the left column of the LP are for guidance. Other figures should be used as necessary for explanations, review, or to answer student questions. The right column of the LP is a duplicate of the startup procedure.

1.3 Startup procedure viewgraphs from Chapter 17 of the manual.

1.4 R-101P Viewgraph Package

2.0 References

2.1 Westinghouse Technology Manual, Chapter 17
2.2 Westinghouse Training Manual
2.3 Callaway Startup procedures, GEN-N- series

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3.0 Learning Objective

No Objectives!

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4.0 Presentation

4.1 Purpose

1. Review control, instrumentation and plant systems.

2. Describe plant operations and systems' alignment during normal, plant startup, shutdown, and power operations.

Note: Students should be encouraged to listen, minimize notetaking, and ask questions as necessary for understanding of the systems and concepts.

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LIST OF VIEWGRAPHS
(In order specified in Lesson Plan)

Figure Number	Title
1. 17-2	Solid Plant Operation
2. 10.3-1	Pressurizer Level Control
3. 3.2-6	RCP Seal and Seal Injection
4. 7.1-1	Main Steam System
5. 10.2-1	Pressurizer Pressure Control
6. 7.2-2	Condensate System
7. 7.2-5	Main Feedwater System
8. 5.1-1	ECCS Composite
9. 4-2	CVCS
10. 12-6	ESF Signals & Actuation
11. 11.2-3	Steam Dump System (Steam Pressure Mode)
12. 4-5	Reactor Makeup System
13. 9-6	Source & Intermediate Range NIs
14. 17-1	RILs
15. 9-7	Power Range NIs
16. 5.3-1	Auxiliary Feedwater System
17. 11.1-1	SGWLCS
18. 11.1-2	Feed Pump Speed Control
19. 6-1	Electrical
20. 12-2	Reactor Trip Composite
21. 8-1	Rod Control System

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APPENDIX 17-1

PLANT STARTUP FROM COLD SHUTDOWN

I. INITIAL CONDITIONS

A. Cold Shutdown - Mode 5

- $K_{eff} < 0.99$
- 0% Rated Thermal Power
- $T_{avg} < 200°F$

B. Pressurizer

Figure 17-2
Figure 10.3-1

1. Temperature approximately 320°F, with a steam bubble established.
2. Level approximately 25% with level control in AUTO.

C. RCS Temperature 150 - 160°F

Note: Temperature may be less than 150°F depending upon decay heat load of the core.

D. RCS Pressure 100 PSIG

- Charging and RHR Letdown Established
- RCS Pressure maintained by RCS Temperature @ 320°F
- RHR System in operation

E. Steam Generators Filled to Wet-Layup

- 100% Level Indication

F. Secondary Systems Shutdown

- Main Turbine and Main Feedwater Pump Turbines on their Turning Gears.

G. Pre-Startup Checklists Completed

II. INSTRUCTIONS

Mode 5=Tavg≤200°F
Mode 4=Tavg>200°F <350°F

A. Heatup from Cold Shutdown to Hot Shutdown (Mode 5 to Mode 4).

1. Permission received from Operations Supervisor for startup
2. Verify Shutdown Rods Withdrawn or Verify Sufficient Shutdown Margin Availability

Figure 3.2-6

3. Verify or establish RCP Seal Injection Flow

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	4. Begin Pressurizer Heatup to increase RCS pressure
	CAUTION: *Do not exceed a heatup rate of 100°F/hr on the pressurizer, 100°F on the RCS or 320°F DT between pressurizer and spray temperature. Use Auxiliary Sprays for Pressurizer-RCS mixing.*
	5. Maintain the RCS temperature < 160°F by adjusting flow through the RHR Heat Exchangers.
	6. Startup Checklists for Technical Specification Requirements completed.
	7. Begin establishing steam generator water levels to 50% on narrow range indication. (Steam Generator Blowdown System)
Figure 7.1-1	8. Open Main Steam Line Isolation Valves
	9. If required commence condensate cleanup.
	10. Establish Condenser vacuum
Figure 17-2 Figure 10.2-1	11. Continue Pressurizer heatup to 430°F. (RCS pressure 325 psig). Use the Low Pressure Letdown Control Valve to maintain letdown flow. RCS pressure control is via heater and spray actuation.
	12. Start the Reactor Coolant Pumps. After five minutes running, sample the RCS for chemistry specifications. Partially open Pressurizer sprays for mixing.
	13. Stop Residual Heat Removal System pumps.
	14. Allow RCS temperature to increase to 200°F.
	15. When RCS temperature reaches 200°F, determine that primary system water chemistry is within specifications.
Figures 7.2-2 & 5	16. When Condensate chemistry is within specifications as determined by chemical lab, align Condensate and Feedwater Systems to normal configuration.
	17. Verify Control Rod Drive Cooling Fans on before RCS temperature reaches 160°F.
	18. Terminate Residual Heat Removal Letdown to CVCS prior to exceeding 350°F and 425 psig.
Mode 3-Tavg≥350°F	**B. Heatup from Hot Shutdown to Hot Standby (Mode 4 to Mode 3).**
	1. Startup Checklist for License Requirements completed.
Figure 5.1-1	2. Complete the ECCS Master Checklist.

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Figure 4-2	3. As the RCS pressure increases, maintain letdown flow 120 gpm by increasing the setting of the Letdown Pressure Control Valve, and by closing the Letdown Orifice Isolation Valves as necessary.
	4. Prior to reaching 1,000 psig in the RCS, open each of the Cold Leg Accumulator Isolation Valves. Remove each valve's power supply.
Figure 3.2-6	5. When RCP No. 1 seal leakoff is > 1 gpm, or RCS pressure >1500 psig, close RCP seal bypass return valve. Verify No. 1 seal leakoff remains > 1 gpm.
Figure 10.2-1 Figure 12-6	6. When RCS pressure reaches 1970 psig, verify Pressurizer Low Pressure Safety Injection Logic Auto reset.
(Review ESF signals)	7. When Tavg exceeds 540°F, verify Steamline Safety Injection Logic Auto reset.
Figure 11.2-3	8. The Steam Dump Control is in Pressure Control Mode, (Set at 1005 psig) to maintain RCS temperature at 547°F.
	9. Place RCS pressure control in AUTO to maintain 2235 psig.
	10. Establish Hot Standby Conditions of 540-547°F Tavg
	C. Heatup from Hot Standby to Power Operations (Mode 3 to Mode 1).
	1. Administrative permission to take the reactor critical has been obtained.
	2. Notify system dispatchers of unit startup and approximate time the generator will be tied on to system.
	3. Notify onsite personnel of reactor startup over P/A system.
	4. If the Shutdown Banks have not been withdrawn complete a Shutdown Margin Calculation (assuming S.D. banks out) and if desired SD margin will exist, withdraw the Shutdown Banks to the fully withdrawn position.
	NOTE: Nuclear Instrumentation shall be monitored very closely in anticipation of unplanned reactivity rate of change.
	5. Calculate the Estimated Critical Boron Concentration for the desired critical control bank rod position (normally 150 steps on Bank D).
Figure 4-5	6. If necessary, conduct a boron concentration change to the estimated critical boron concentration. Equalize boron concentration between the Reactor Coolant Loops and the pressurizer by turning on Pressurizer Backup Heaters.

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	NOTE: Nuclear Instrumentation shall be monitored very closely in anticipation of unplanned reactivity rate of change.
	NOTE: Block the Source Range High Flux Level at Shutdown Alarm at both Source Range Panels.
Figure 9-6	7. Withdraw the Control Bank Rods in Manual and take the reactor critical. a. Block Source Range Trip at P-6 b. Record Critical Data at 10^{-8} amps.
Figure 17-1	8. If the control bank height at criticality is below the Minimum Insertion Limits for the 0 percent power conditions. a. Re-insert all control bank rods to the bottom of the core. b. Recalculate the Estimated Critical Boron Concentration . c. Borate to the new Estimated Critical Boron Concentration. d. Withdraw the Control Bank rods in Manual and take the reactor critical.
Figure 9-7	9. Withdraw rods to bring reactor power to approximately 1% on power range indicators and select the highest Power Range channel to be recorded on the NR 45 recorder.
Figure 5.3-1 Figure 11.1-1&2	10. Start a Main Feedwater Pump at 1% power and maintain Steam Generator levels at 50% narrow range level indication during secondary plant start up by throttling the Feedwater Bypass Regulating Valves and operating the Master Feed Pump Speed Controller and the individual SGFP Control Station in Auto..
	CAUTION: Coordinate all Steam Generator steam removal and significant Feedwater changes with the Reactor Panel Operator while Rod Control is in Manual.
	11. Turbine has been on turning gear at least one hour.
	12. Increase reactor power by manual adjustment of the Control Bank until the Steam Dump is bypassing steam flow equivalent to 8 percent nuclear power.
Figure 6-1	13. Verify the Unit Auxiliary and Startup transformer cooling systems are aligned for auto operation.
	14. Start the turbine, bring it up to speed, and connect the Generator to the grid. Transfer station power from the Startup transformer to the Unit Auxiliary transformer.
	15. Increase Generator load at the desired rate, while maintaining Tavg by Manual Rod Control.
	16. Transfer Feedwater flow from Bypass valves to Main Feed Regulating Valves. Maintain programmed level during this process.

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Figure 12-2 (Review Rx Trips)	17. When reactor Power increases above 10 percent, ensure the Nuclear At Power Permissive P-10 light comes on and the Turbine At Power Permissive P-13 and At Power Permissive P-7 lights clears.
	18. Manually block the Intermediate Range Reactor Trip and the Power Range Low Setpoint Reactor Trip after P-10 has been actuated.
Figure 8-1	19. When turbine power has increased above 15 percent, and Tavg equals Tref, transfer the Rod Control System to Automatic.
	20. After Rod Control System is placed in Automatic, check steam pressure less than Steam Dump Set Point and steam dump valves fully closed, then transfer Steam Dumps to T_{avg} Mode.
	21. Above 15 percent power, transfer Steam Generator Feedwater Regulating Valve Control to Automatic when level is at setpoint and steam flow equals feed flow.
	22. Continue turbine load increase to 100%.
	a. Start Secondary System components as required during power escalation. Additional components would include items such condensate pumps, heater drain pumps, feedwater pumps, and condenser circulating pumps.
	b. Maintain rate of load increase within plant design limits. These limits would include the loading limits imposed upon the main turbine and the limits imposed by boron dilution rates.